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**Sent:** Friday, November 22, 2013 11:14 AM  
**To:** FRUEH Terry  
**Subject:** FW: brief input on process of doing SR  
In case you do not have a copy of the final report, it is attached.  
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**From:** FRUEH Terry  
**Sent:** Friday, November 22, 2013 10:56 AM  
**To:** FRUEH Terry  
**Subject:** brief input on process of doing SR  
All,

I am writing an article on the entire experience of this systematic review for stream temperature & shade. I would appreciate your feedback as external parties to ODF that were included in the review process.

I am open to whatever type of input you would like to provide, and here is some of the type of input I am looking for:

- What are your thoughts about the final report? Did the protocol strengthen the review, and if yes, how? Were there drawbacks to using a protocol and a consistent and transparent process?
- What are your thoughts about being included at different stages (reviewing the protocol, assessing the list of included studies, reviewing the draft report) of the review process? What were the strengths and weaknesses of this approach, from your perspective?
- Would you like to see us do anything differently the next time? What could we have done to improve it this time?

Thanks,  
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# **Effectiveness of riparian buffers at protecting stream temperature and shade in Pacific Northwest Forests: A systematic review**

**Final Report  
September 2013**

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## **Key to abbreviations and acronyms**

Board - Oregon Board of Forestry

cfs - cubic feet per second (a unit of streamflow)

FPA - Forest Practices Act (for private land)

FMP - Forest Management Plan (for Oregon State Forests)

HWC - hardwood conversion

OAR - Oregon Administrative Rules

ODEQ - Oregon Department of Environmental Quality

ODF - Oregon Department of Forestry

ORS - Oregon Revised Statutes

PCW - Protecting Cold Water criterion

RipStream – Riparian Function and Stream Temperature Study

RMA - Riparian Management Area

RSERT - RipStream External Review Team

SR - Systematic Review

## **Executive Summary**

### **ES 1. Introduction**

#### ***ES 1.1 Background***

The Oregon Board of Forestry (“Board”) made a finding of degradation that stream protections afforded to small- and medium-sized fish-bearing streams under the Forest Practices Act (FPA) were not likely protective of the Oregon Department of Environmental Quality (ODEQ) Protecting Cold Water (PCW) criterion. This criterion prohibits human activities, such as timber harvest, from increasing stream temperatures by more than 0.3 °C, for all sources taken together at the point of maximum impact, at locations critical to salmon, steelhead or bull trout. The Board’s finding was based on scientific outcomes of the Oregon Department of Forestry (ODF) Riparian and Stream Function (RipStream) monitoring project. ODF has therefore undertaken a systematic science review in support of a riparian rule analysis to address concerns about meeting the PCW criterion.

The geographic scope of the RipStream findings is limited to streams in the Coast Range and Interior Geographic Regions of Oregon (as defined in Oregon Administrative Rules [OAR] 629-635-0220). The geographic extent of the rule analysis is therefore limited to Geographic Regions in western Oregon. This limitation is due to the riparian vegetation, climate and hydrologic characteristics of eastern Oregon being significantly different enough from those included in the RipStream study to preclude extending a rule change to eastern Oregon. Whether all five western Oregon Geographic Regions, or only a subset of the five, will be included in the rule analysis has yet to be determined. At their July 2012 meeting, the Board approved consideration of 16 rule alternatives (contributed by stakeholders) for meeting the PCW criterion during harvest operations.

#### ***ES 1.2 Objective of the Review***

This systematic review is designed to provide scientific guidance to the Board on the efficacy of the 16 rule alternatives in addressing the following rule analysis objective developed by the Board at their April 2012 meeting:

**Establish riparian protection measures for small and medium fish-bearing streams that maintain and promote shade conditions that insure, to the**

**maximum extent practicable, the achievement of the Protecting Cold Water criterion.**

A secondary purpose of this review is to inform the Board's decision on the geographic extent of the rule analysis within western Oregon.

## **ES 2. Methods**

A protocol for this systematic review was developed following guidance on conducting systematic reviews in the natural resource sciences. This method was selected because it provides for rigor and transparency concerning how studies are searched for, which ones are included in the review, and how they are analyzed. This protocol provided a road map for how to conduct the review of scientific literature relevant to the focused question:

**For small and medium streams in the western Pacific Northwest, in or adjacent to forest harvest operations, what are the effects of near-stream forest management on stream temperature and/or riparian shade?**

The review seeks to answer this question with evidence, as opposed to the authors' interpretation of such evidence, from existing studies. Studies are rigorously screened for quality and relevance to this question. Finally, the entire process of conducting the review allows for greater inclusion of review partners (e.g., stakeholders and technical experts), as all steps of the review are fully documented for transparency. ODF requested and received input from these partners, thereby strengthening the quality of this systematic review.

To minimize bias in the review, ODF hired external scientists to review the studies and synthesize their analyses. ODF coordinated the work of the scientists and all other partners, and wrote portions of this report.

## **ES 3. Results and Synthesis**

The systematic search found 1,456 publications, of which 25 passed all the inclusion criteria for the review. Of included publications, 10 were governmental reports, 13 were peer reviewed journal articles, and two documents were unpublished and in review. Since several of the publications are from the same study, these 25 publications represent 19 distinct studies. The publications were divided between those measuring shade only (9), temperature only (7), or both (9).

### ***ES 3.1 Geographical ranges and physical settings***

Due to the geographically-focused review question, all publications were limited to areas within, or similar to, Oregon west of the Cascade crest. Considered in terms of ODF Geographic Regions, twelve publications had study sites in the Coast Range, two in the Western Cascades, and eleven in the Interior.

To gain insight on geographic extent of the rule analysis, effectiveness of buffer prescriptions were compared between ODF Geographic Regions. These comparisons revealed no obvious pattern in differences by Geographic Region for the various buffer prescriptions. The inability to discern a pattern may be influenced by the small amount of data available for robust comparisons.

### ***ES 3.2 Rule Alternatives***

Each reviewed publication was rated for relevance to the sixteen rule alternatives proposed by the Board. Seven of the sixteen rule alternatives had at least one highly relevant study (i.e., the study provides quantitative data that addresses the effectiveness of a particular prescription of a rule alternative at protecting stream temperature or shade). Nine rule alternatives only had studies that were of low relevance, and therefore are not examined because they lack evidence concerning their ability to protect cold water and shade in western Oregon.

Only two classes of rule alternatives were shown to be clearly effective at protecting cold water or shade by high quality studies (quality gauged via a “confidence score”): Variable retention and Derived no-cut buffers. It is important to note the large degree of variability in the findings - both across publications and within publications containing numerous sites – indicates there would be uncertainty in identifying a buffer prescription that would achieve the PCW criterion. Additionally, we recognize that contributing factors (i.e., exclusive of characteristics of each buffer studied) may influence stream temperatures. These factors were not systematically assessed for this review due to the different ways contributing factors were considered and incorporated into each study.

The variable retention group includes two Board-approved rule alternatives considered in the review (State Forest Management Plan [FMP] and Forest Practices Act [FPA]), and studies of two other rules (ODF’s previous riparian protection rule, and Alaska’s version of the FPA).

The only FMP study available, which had a high confidence score, showed that both shade (average change in shade: -1%) and temperature (average change in temperature: 0.0 °C) were protected using that prescription. Of the four studies that examined the FPA, results showed a change in percent shade between -0.5% and -9%, yet none of those with temperature data met the PCW criterion. Confidence scores for these studies ranged from low to high. Of the other two variable retention prescriptions tested, one study had some sites that appeared to protect shade. This study was based on the ODF riparian rules from before 1994, had a low confidence score, and the average change in shade was -19% (temperature data were not collected).

No-cut buffers were the most extensively studied of all the rule alternatives with 12 studies. It should be noted that many of the studies included multiple sites of differing buffer widths and thus their data could not be averaged in a meaningful way. Nearly all studies that examined shade had some sites wherein shade was protected, and their confidence scores ranged from low to high. Four of seven studies that measured stream temperatures had some sites that appeared to meet the PCW criterion, three of which had a range of buffer widths.

Three other rule alternatives were assessed for their effectiveness at protecting cold water and/or shade. The shrub shade alternative had a low confidence study with three sites, and came close to, but appeared to not achieve, the PCW criterion. Similarly, the south-sided buffers had one study of low confidence with three sites. The results show this buffer was protective of shade, and came close to, but appeared to not achieve, the PCW criterion.

The final rule alternative, plan for alternate practices, acts as a catch-all for riparian management prescriptions that did not fit into other rule alternatives. As such, it includes six different prescriptions analyzed in seven studies. Two prescriptions (undefined “site specific” plans, and hardwood conversions (HWC) following each of Washington and Oregon’s rules) had sites wherein shade was protected (low to medium confidence scores), and only Washington’s HWC (low confidence score) had some sites wherein the PCW criterion appeared to be met.

### ***ES 3.3 Summary***

This review provides three key components that inform the Riparian Rule Analysis:

1. Nineteen studies (with 25 publications) have assessed the effectiveness of riparian buffers to protect cold water or shade in forest harvest operations in the Pacific Northwest. These studies vary widely in both their designs and in confidence of their findings.
2. The evidence from this suite of studies only supports two classes of rule alternatives as effective in meeting the Protecting Cold Water criterion:
  - A. Variable retention buffers (including State Forest Management Plan)
  - B. No-cut buffers
3. No consistent pattern presented itself when comparing temperature and shade results between Geographic Regions of western Oregon, although there are not enough data available to support this assessment with a high degree of confidence.

# **1. Introduction**

## **1.1 Background**

Stream temperature is an important control on aquatic community composition and the chemical and biological processes that support them (Beitinger and Fitzpatrick, 1979). Many Oregon streams support several cold-water fisheries (e.g., salmon, steelhead, cutthroat) which are important to the region's economy, culture, and recreational activities. These fish are thermally adapted to specific water temperature regimes for various life stages such as egg and smolt survival, spawning, and adult migration (Richter and Kolmes, 2005). These regimes are affected by several natural processes including direct exposure to sunlight, the transfer of thermal energy between the stream and its environment, evaporation, water exchange with groundwater or the hyporheic zone, and others (Brown, 1969; Johnson, 2004). Of these factors, direct exposure to sunlight is a major contributor to maximum daily summer temperatures for smaller streams, and this exposure may increase following timber harvest (Brown and Krygier, 1970; Johnson, 2004; Sinokrot and Stefan, 1993). Therefore, maintaining riparian shade may serve as an effective tool for minimizing the increases in stream temperature for small- to medium-sized streams during the summer months when maximum stream temperatures are observed (Johnson, 2004).

Oregon has enacted timber harvest regulations to maintain shade on streams following timber harvest (Oregon Department of Forestry, 2010). Timber harvest operations are considered in compliance with ODEQ water quality standards (ODEQ, 2004) if harvest operations comply with the Forest Practices Act (FPA; Oregon Revised Statutes [ORS] 527.770). The Oregon Department of Forestry (ODF) must establish best management practices and rules that will meet state water quality standards and periodically conduct studies to determine if the FPA effectively meets state water quality standards (ORS 527.765, 527.710).

ODF initiated its Riparian Function and Stream Temperature (RipStream) monitoring project in 2002 to assess the effectiveness of the FPA and State Forests standards at complying with ODEQ water quality standards for temperature. One of the temperature criteria examined was the Protecting Cold Water (PCW) criterion, which is designed to prevent warming of salmonid-bearing streams as a result of anthropogenic activities. This criterion prohibits human activities, such as timber harvest, from increasing stream temperatures by more than 0.3 °C at the

point of maximum impact where: a) salmon, steelhead or bull trout are present; b) streams are designated as critical habitat for salmonids; or c) streams are necessary to provide cold water to a) (Oregon Administrative Rules [OAR] 340-041-0028 (11)). An analysis of the pre- and post-harvest data indicated that the PCW criterion was likely not being met at all study sites with FPA buffers (i.e., these sites frequently exhibited temperature increases greater than 0.3 °C; [Groom et al., 2011a]). This finding of degradation (officially approved by the Oregon Board of Forestry [Board], January, 2012) initiated an FPA riparian rule analysis (ORS 527.714(5)(a)). As part of this analysis, stakeholders contributed, and the Board approved, 16 alternative methods of riparian management as options for meeting the PCW criterion during future near-stream harvest operations.

The geographic scope of the findings of degradation are based on Groom et al. (2011b), which studied streams in the Coast Range and Interior Geographic Regions of Oregon (as defined in OAR 629-635-0220). While the exact geographic extent of the rule analysis is yet to be determined, it will be limited to western Oregon. This limitation is due to the vegetation, climate and hydrologic characteristics of eastern Oregon being significantly different enough from those included in the RipStream study to preclude extending a rule to eastern Oregon.

This systematic review (SR) was completed to fulfill a requirement of the rule analysis process: proposed rules must reflect available scientific information (ORS 527.714 (5)(c)). The SR will also serve to inform the decision on the geographic extent of the rule analysis relative to the RipStream findings on FPA sufficiency. Therefore, this SR will, through evaluating a focused question, directly assist in evaluating the 16 alternative scenarios for riparian management and help inform the ODF rule analysis. However, this review does not recommend which alternative is the best to choose, nor explicitly define a particular rule prescription. ODF staff will draft a report with Board recommendations based on the outcomes of the SR and data analyses related to the rule analysis.

## **1.2 Objective of the Review**

This systematic review is designed to provide scientific guidance, per ORS 527.714 (5)(c), to the Board in addressing the following objective of the rule analysis, developed by the Board at their April 2012 meeting:

***Establish riparian protection measures for small and medium fish-bearing streams that maintain and promote shade conditions that insure, to the maximum extent practicable, the achievement of the Protecting Cold Water criterion.***

Small streams are defined as having average annual flows  $\leq 57$  L/s (2 cfs), and medium streams are defined as having flows  $> 57$  L/s (2 cfs) and  $\leq 283$  L/s (10 cfs; Oregon Department of Forestry, 2010). Fish-bearing streams are those for which anadromous, game, or threatened and endangered fish presence has been observed or modeled. Specifically, this review is designed to provide insight on the efficacy of the 16 rule alternatives that were approved by the Board at their July 2012 meeting (Table A.5). A secondary purpose is to inform the Board's decision on the geographic extent of the rule analysis.

## **2. Methods**

This section summarizes the protocol for conducting the systematic review (for details of the protocol, refer to Appendix A). Note that blank copies of the tables to be completed by the reviewers are listed in Section A.6, whereas the associated completed tables are in Appendix B. The protocol was approved by the Board (March 2013), and was modified slightly during the review process (Appendix A).

### **2.1 Purpose of protocol for systematic review**

Protocols provide a road map for how to conduct a systematic review of scientific literature relevant to a narrowly-defined question (Centre for Evidence-based Conservation, 2013). A systematic review seeks to answer this question with evidence, as opposed to the authors' interpretation of such evidence, from existing studies that are rigorously screened for quality and relevance to this question. The structured process provides for rigor and transparency concerning how studies are searched for, which ones are included in the review, and how they are analyzed. This process also allows for a review to be either updated in the future, or completed by another party.

### **2.2 Review partners**

Numerous partners strengthened the quality of this systematic review. ODF staff composed an initial draft of the protocol, then obtained input on it from a group of stakeholders and the RipStream External Review Team (RSERT). These groups included university, federal,

forest industry, and state scientists; staff from the Oregon Departments of Forestry, Environmental Quality, and Fish & Wildlife; and non-governmental organizations (e.g., Wild Salmon Center, Pacific Rivers Council). Similarly, a reference librarian from the Oregon State Library assisted in refining the search strategy. Finally, ODF coordinated the work of these partners, plus that of the external reviewers. All partners had the opportunity to provide input on:

- The protocol and question for this review;
- A draft list of publications to consider for inclusion in the review to assess if any studies were not found;
- A draft list of included publications to assess whether or not the inclusion criteria were appropriately applied;
- A draft of the completed SR report.

To minimize bias in the review, ODF hired external scientists (“the reviewers”, Drs. Nicole Czarnomski and V. Cody Hale) to conduct the review. These reviewers cross-checked their work by reviewing the same subset of studies (including comparisons of assessments for study relevance, quality, and data extraction). Each reviewer then independently reviewed half the remaining studies included in the review. Where the reviewers, in coordination with ODF, found ways to improve the protocol, it was modified with alterations documented in Appendix A. ODF staff helped calculate numbers for figures (double-checked by Drs. Czarnomski and Hale) and provided additional support. After analyzing the articles, the reviewers collaboratively wrote this report synthesizing their analyses. Table 1 outlines contributing authors of each section of the report.

**Table 1. Authors for each section of the report.**

<b><u>Report section*</u></b>	<b><u>ODF staff</u></b>	<b><u>Drs. Czarnomski &amp; Hale</u></b>
Executive Summary	X	
1, 2, 3.1	X	
3.2-3.7, 4		X
3.3	X	X
A, C, D, E	X	X
Completed Table A.6.1	X	
Completed Tables A.6.2-4		X

\*Each party reviewed the work of the other party.

## **2.3 Review questions**

### ***2.3.1 Primary review question***

Systematic reviews are designed to assess a body of literature through the lens of a focused question regarding the efficacy of active treatments, rather than a general topic of concern to policy or practice. The question should be value-free to the extent possible, answerable in scientific terms, and specify the subject, treatment, comparator, and outcome(s) of interest. The question is also important since it is used to generate terms used in the literature search and to determine relevance criteria for including or excluding articles from the review.

The elements of this review's question are based on the rule analysis objective and the finding of degradation, and were developed in stages. ODF staff (T. Frueh, J. Groom, and M. Allen) developed a draft review question and protocol. The question was refined in consultation with representative stakeholders and RSERT to ensure the question's importance and appropriateness of scope for this review. The question was then further refined with ODF input. Although the rule objective focuses on fish-bearing streams, "fish-bearing" was not included in the review question because many, if not most, studies do not explicitly state whether or not they were conducted in streams determined to be fish-bearing according to ODF protocol. Had we included "fish-bearing", the number of included studies would have dropped substantially, and thereby increasing the likelihood that we miss important evidence. The review question is:

***For small and medium streams in the western Pacific Northwest, in or adjacent to forest harvest operations, what are the effects of near-stream forest management on stream temperature and/or riparian shade?***

### ***2.3.2 Secondary question***

This review evaluated differences between studies that might explain variations among study outcomes. These differences may be due to effects modifiers (see Section A.3.3 for more information on these modifiers), and this secondary question explicitly addresses the causes of these differences. To the extent that relevant information is available in reviewed studies, this secondary question was addressed:

***For small and medium streams in the western Pacific Northwest, in or adjacent to forest harvest operations, how do effects modifiers (e.g., discharge, substrate characteristics, length of buffers, stream aspect), in combination with near-stream forest management, change stream temperatures or riparian shade?***

### **2.3 Search strategy**

An important aspect of systematic review is the use of a search strategy that specifies, *a priori*, how a comprehensive and unbiased sample of the literature will be searched. We decided to search as widely as possible, then use rigorous inclusion criteria to determine which studies to include. All publications found in each searched source were saved in a database, except for internet searches from which the first 100 results were reviewed for relevant publications (this restriction follows CEBC [2013] guidance). Results with indeterminate information (e.g., incomplete citation) or duplicates were discarded. For every search, the following information is documented (see Data Supplement 1, Lit-Search\_Filter.xls):

- Date when search was conducted
- Database, search engine, website, library, or professional contact that was queried
- Exact search strings used

### **2.4 Study inclusion criteria**

Study inclusion criteria are predefined to ensure an objective selection of the relevant literature. For this review, the studies must directly inform the primary review question in the context of the rule alternatives and rule objective. Only primary studies (i.e., studies with original data, not reviews, modeling, or meta-analyses) were included since ODF wants to base the rule analysis on evidence, not authors' interpretation of the evidence. While peer-reviewed articles are the gold standard in science, we decided to include "gray literature" (i.e., articles that might have less rigor in either peer-review or research methods / analysis, e.g., government reports, graduate theses) and manuscripts in review because some of these studies are most relevant to the review question. This relevancy stems from a common requirement that agencies (e.g., ODF, Washington Dept. of Natural Resources) assess the effectiveness of their respective rules via studies. In addition, only studies that measure the effects of recent forest harvests, with near-stream areas managed for protecting water (e.g., similar to OAR 629-635-0100), on stream temperature or riparian shade were included since these elements are essential to inform the objective of the rule analysis that provides the impetus for conducting this study. Restricting studies to those where harvest was recent (<5 years) with respect to data collection is warranted due to the decline, with time, of adverse impacts of harvest on stream temperature and riparian shade (Hale, 2007; Johnson and Jones, 2000). The final inclusion criteria are:

- Studies must have proper controls with which to measure the effects of buffer treatments;
- Studies must have been conducted in sites with similar stream sizes as ODF's classification of small and medium streams (Oregon Department of Forestry, 1994); and,
- Studies must have been located in similar forests as those of western Oregon.

Inclusion criteria are further detailed in Table A.6.1.

With these criteria in mind, inclusion was determined initially on viewing the titles of articles. When titles provided insufficient information to determine meeting all inclusion criteria, the ODF review coordinator read abstracts to determine inclusion. Where there was still insufficient information to make a decision, an article's inclusion was determined by reading the full text. Studies that meet all inclusion criteria were reviewed by the external reviewers. For transparency, the fate (i.e., inclusion or exclusion), and basis for this decision, of each publication found in the search are documented in Data Supplement 1.

## **2.5 Potential effects modifiers**

Although studies may have very similar methods, they may show differences in the measured outcomes. These differences may be due to circumstances ("effects modifiers") that alter the outcomes. For example, two studies may have identical buffer widths, yet if they have different buffer lengths, they might exhibit different changes in stream temperatures. Thus, these effects modifiers are important to consider when synthesizing the information extracted from studies. The role effects modifiers played in study outcomes is assessed using Table A.6.2 and discussed in the narrative synthesis (Section 3).

## **2.6 Data extraction strategy**

When conducting a systematic review, it is important to extract both information about the studies and their respective primary data. This information focuses the review on evidence instead of authors' interpretation of the evidence. Data extraction tables allow for objective, consistent, and transparent extraction of these data. In addition, these tables help to highlight gaps in our understanding. Each study's data were compiled using Table A.6.2. This table was developed by modifying those of Bowler et al. (2008) and Burnett et al. (2008), testing data extraction with several studies, and with input from RSERT and stakeholders. Reviewers also assessed various components (e.g., bias, effects modifiers) that provide a more complete

understanding of the context, relevance and relative strength of studies (Completed Tables A.6.2).

## **2.7 Study quality assessment and relevance**

When synthesizing data from the studies, it is important to consider both the quality of each study and its relevance to the review question. For example, a study might have directly addressed the review question, yet was poorly conducted so as to provide little confidence in the study's results. Conversely, a study may have been conducted very well, yet has only weak relevance to the review question.

External reviewers completed tables that enable quick, objective comparisons of studies. Table A.6.3 addresses the quality of studies by determining e.g., the rigor of their controls and number of replicates. A summary metric, the Confidence Score, combines the various aspects that make for a high quality study (Table A.6.3). This metric is designed to help assess the quality of the information when looking at the effectiveness of a particular buffer type. This table also determines study relevance to the review question by determining how close studies are geographically and in stream size to those of Groom et al. (2011a). Table A.6.4 determines whether studies directly or indirectly addressed a rule alternative. Notes additionally provided by reviewers using Table A.6.2 further illuminate study quality and relevance (e.g., robustness of study measures, sources of bias, consideration of effects modifiers).

## **2.8 Data synthesis**

To make sense of the information extracted and analyzed from the studies, a narrative synthesizes the information collected in Completed Tables A.6.2-A.6.4 (Appendix B). This synthesis assesses the differences and commonalities between riparian management scenarios used in studies, their respective outcomes, and Geographic Regions. For each rule alternative, the synthesis discusses:

- Number of studies that directly or indirectly address the alternative;
- Results discussed by Geographic Region;
- Evidence from a suite of studies regarding the effectiveness of the alternative, including:
  - range of variation in metrics defining each alternative (e.g., buffer width, basal area retention)
  - range of variation in outcomes measured

- degree of effectiveness at protecting cold water or riparian shade
- Role of effects modifiers in the stream temperature and riparian shade outcomes that were measured; and
- Significant gaps in our understanding.

### **3. Results and Synthesis**

#### **3.1 Literature search and filter**

In a search of studies relevant to this review, 1,456 studies were identified, of which 25 met all criteria for inclusion in the review (Table 2; Data Supplement 1, Lit\_Search\_Filter.xls). Of studies excluded from the review, approximately 80% were rejected by reading the title, ~10-15% were rejected by reading the abstract, and the remainder required reading a portion of the complete text. When stakeholders and technical experts were asked to provide input on the results of the literature search and filtering process, zero comments were received.

#### **3.2 Summary of studies and management prescriptions**

##### ***3.2.1 Summary of publications***

Of the 25 publications reviewed, 10 were governmental reports, 13 were peer reviewed journal articles, and two publications were unpublished and in review (Table 2). Of the publications considered to have a high focus on the SR question, they were evenly divided among those providing measures of temperature and those measuring shade (Table 3). However, government reports more often provided measures of shade (90% of publications) and peer review / in review articles more often provided measures of temperature (91% of publications). Only four publications were considered to have a low relevance to the SR question (i.e., they were indirectly related, though still included because they met the inclusion criteria and provided useable data), and they were all peer reviewed articles that primarily measured shade (Table 3; Completed Table A.6.3).

**Table 2. Summary information on publications included in the review.**

ID*	Study	Location (Georegion/# of sites)†	Pub. type <sup>a</sup>	Rel.?Δ	Buffer Prescriptions±	Conf. Sc.**	Effectiveness data (location of data within a publication, method of extraction if applicable)††	Measurements																	
								Temp.	Shade																
A	Allen and Dent, 2001	OR (CR/18)	Gov't.	Y	14 no-cut buffers (20-70 ft.; 6-21 m), 2 riparian conifer restorations (RCR), 2 site-specific (SS) plans	7	Range in difference in shade (Table B1, excluding large streams and Blue Mtn. data, measured with respect to avg. forested shade) no-cut (n=14): -38 to -4%; RCR (-28, -6%), SS (-9, 0%)		X																
B	Brazier and Brown, 1973	OR (CR/7, I/4)	Gov't.	Y	11 no-cut buffers (10-60 ft.; 3-18 m)	5	Range in change in canopy cover (Fig. 5; 10-60' buffers values compared with those at 100'): 0 to -60%  Observed temp. change (Table 1) +0.6 to +5 °C	X	X																
C	Brosofske et al., 1997	WA (Cascades)	PR	N	14 no-cut buffers (26-141 ft.; 8-43 m)	6.5	Range in change in radiation (Fig. 8): 0 to +0.1 kW/m2		X																
D	Danehy et al., 2007	OR (CR/7)	PR	N	7 no-cut buffers (49 ft.;15 m; Note: outside of buffers was thinned and not clearcut)	7	Change in insolation (Table 1, measured with respect to mean mature; MJ/m2/day): uncut (mean: +95, std. dev.: ±89), thinned (mean: +137, std. dev.: ± 28)	X	X																
E	Dent, 2001	OR ( CR/4, I/7)	Gov't.	Y	1 no-cut buffer (70 ft.; 21 m); 3 riparian conifer restorations; 7 standard Forest Practices Act (FPA) prescriptions.	6.5	Change in cover (averages for medium (M) and small (S) streams west of Cascade crest, Table 6): No-cut, medium (n=1): -2%; FPA: small (n=3): -9% (range -4 to -16), Med (n=4): -4.5% (range -18 to +4); RCR: small (n=2): -20% (-6, -34); Med. (n=1): -36%		X																
F <sub>1</sub>	Dent and Walsh, 1997	OR (CR/7, I/4)	Gov't.	Y	4 standard FPA prescriptions; 4 hardwood conversions (HWCs); 3 HWCs limiting openings on south side of streams	6	<div>From Table 3:</div> <table><tr><td>Rule</td><td>n</td><td>Avg. Change 7-D max., C (range)</td><td>Avg. change in cover, % (range)</td></tr><tr><td>FPA</td><td>4</td><td>+1.4 (+0.4 to +1.8)</td><td>-0.5 (-18 to +9)</td></tr><tr><td>HWC</td><td>4</td><td>+1.7 (+0.4 to +3 2)</td><td>-8.5 (-20 to +6)</td></tr><tr><td>S. Side</td><td>3</td><td>+0 5 (+0.0 to +1.4)</td><td>-4 (0 to -7)</td></tr></table>	Rule	n	Avg. Change 7-D max., C (range)	Avg. change in cover, % (range)	FPA	4	+1.4 (+0.4 to +1.8)	-0.5 (-18 to +9)	HWC	4	+1.7 (+0.4 to +3 2)	-8.5 (-20 to +6)	S. Side	3	+0 5 (+0.0 to +1.4)	-4 (0 to -7)	X	X
Rule	n	Avg. Change 7-D max., C (range)	Avg. change in cover, % (range)																						
FPA	4	+1.4 (+0.4 to +1.8)	-0.5 (-18 to +9)																						
HWC	4	+1.7 (+0.4 to +3 2)	-8.5 (-20 to +6)																						
S. Side	3	+0 5 (+0.0 to +1.4)	-4 (0 to -7)																						

ID*	Study	Location (Georegion/# of sites)†	Pub. type <sup>a</sup>	Rel.?Δ	Buffer Prescriptions±	Conf. Sc.**	Effectiveness data (location of data within a publication, method of extraction if applicable)††	Measurements	
								Temp.	Shade
G <sub>2</sub>	Gomi et al., 2006	BC	PR	Y	No-cut buffers (1 33 ft/10 m, 2 98 ft./30 m)	9.5	Mean (maximum) treatment effect summer maximum temp. (Table 3): 10 m: +1.0 (+4.1) °C; 30 m: +0.2 (+1.4) °C	X	
H <sub>3</sub>	Groom et al., 2011a	OR (CR/30, I/3)	PR	Y	18 standard FPA prescriptions; 15 State Forest Management Plan (FMP) prescriptions	12	Avg. temp. change (text, p. 1626): FPA: 0.7 °C (range -0.9 to +2.5 °C); FMP: 0.0 °C (range -0.9 to +2.3 °C) Avg. change in shade (text p. 1627): FPA: -7%; FMP: -1%	X	X
I <sub>3</sub>	Groom et al., 2011b	OR (CR/30, I/3)	PR	Y	18 standard FPA prescriptions; 15 State Forest Management Plan (FMP) prescriptions	12	Chance of exceeding PCW standard (increase of 0.3 °C): FPA: 40%; FMP: 9%	X	
J <sub>3</sub>	Groom et al., 2013	OR (CR/30, I/3)	IR	Y	18 standard FPA prescriptions; 15 State Forest Management Plan (FMP) prescriptions	12	Number of sites exceeding 16 or 18 °C criteria: 3	X	
K	Hunter, 2010	WA (Coast Ranges)	Gov't.	Y	7 hardwood conversions	6	Range in difference of mean shade (pre-post, from text at each site): -3 to -13% Range in temperature changes (difference in temp. at upstream vs. downstream end of harvest unit, from figure for each site): -1.8 to +2.0 °C.	X	X
L <sub>4</sub>	Jackson et al., 2007	WA (Coast Ranges)	PR	N	3 no-cut buffers (7-69 ft.; 2-21 m); 2 nonmerchantable tree buffers	7	Change in cover (Table 4; average for both post-harvest years) no-cut: -54% (range: -15 to -78%); nonmerchantable tree: -58% (-35, -80%)		X
M <sub>4</sub>	Jackson et al., 2001	WA (Coast Ranges)	PR	Y	3 no-cut buffers (7-69 ft.; 2-21 m); 2 nonmerchantable tree buffers	6	Range in change in temperature (Table 3) no-cut buffers: -0.5 to +2.6 °C; nonmerchantable tree buffers: +2.8 to +4.9 °C	X	
N <sub>5</sub>	Janisch et al., 2012	WA (Coast Ranges)	PR	Y	6 no-cut buffers (33-49 ft.; 10-15 m); 5 patch buffers	12	Mean disturbances, Maximum Daily Temperature (Figure 3b; range): no-cut: +0.7(0.0 to +1.9) °C; patch: +0.6 (+0.1 to +1.2) °C Change in canopy-topographic density (text p. 408), %: no-cut: -8; patch: -18	X	X
O <sub>2</sub>	Kiffney et al., 2003	BC	PR	Y	No-cut buffers (3 33 ft./10 m, 3 98 ft./30 m)	6	Difference in PAR, μmol/m <sup>2</sup> /s (Fig. 2): 10 m: +78 ; 30 m: +8	X	X

ID*	Study	Location (Georegion/# of sites)†	Pub. type <sup>a</sup>	Rel.?Δ	Buffer Prescriptions±	Conf. Sc.**	Effectiveness data (location of data within a publication, method of extraction if applicable)††	Measurements	
								Temp.	Shade
							Increase in maximum summer water temperatures with respect to control reaches (text p. 1066): 10 m: 3 °C; 1.6 °C		
P	Martin, 2004	SE AK	Gov't.	Y	3 RMAs with inner no-cut (25 ft.; 8 m) & outer partial cut (41 ft.; 12 m)	8	Avg. change in shade (difference pre-post means for each reach, Table 3): -29% (-24%, -26%, -38%)		X
Q	Morman, 1993	OR ( CR/9, I/8)	Gov't.	Y	17 Variable-retention RMAs (39-154 ft.; 12-47 m)	6	Change in aquatic area shading (compiled from data on pp. 49-117): +1 to -35%		X
R	Newton and Cole, 2013a	OR (CR/1, I/2)	IR	Y	3 standard FPA prescriptions <sup>aa</sup>	11	Average change 7-day moving mean maxima temperature over the reach, post- pre (Figure 7): +0.6 °C (range: -0.1 to +1.3 °C)	X	
S	Newton and Cole, 2013b	OR (CR/1, I/1, WC/1)	PR	Y	3 shrub only buffers <sup>aa</sup>	7	Average temperature differentials across 180 m shrub shade reaches, with respect to pre-treatment data <sup>ΔΔ</sup> : +0.7 °C (range -0.3 to +1.2 °C)	X	
T	Rashin et al., 1992	WA (Cascades, Coast ranges)	Gov't.	Y	9 no-cut buffers (5-190 ft.; 1.5-58 m)	4	Range in median max. daily water temp. differentials (Table 1): +0.1 to +4.6 °C	X	
U	Schuett-Hames et al., 2012	WA (Cascades, Coast ranges)	Gov't.	Y	13 with ½ of length no-cut buffers (50 ft.; 15 m), ½ length cut to stream edge; 3 with radial no-cut buffers at point of initiation of perennial flow (PIP) (56 ft. (17 m) radius)	7.5	Average change in shade (Table 49; average of 3 years difference between mean value for patch type and that of reference) 1/2-length no-cut buffers: -29% (range -24% to -38%); PIP: -30% (range -28% to -34%)		X
V	Steinblums et al., 1984	OR (I/17 to 19, WC/21 to 23)	PR	Y	40 no-cut buffers (25-115ft.; 8-35 m)	5	Fig. 2: Range in change in cover (Fig. 2; measured with respect to value at 140°): 0 to -73%		X
W	Veldhuisen and Couvelier, 2006	WA (N. Cascades)	Gov't.	Y	9 no-cut buffers (16-105 ft.; 5-32 m)	6	Range in change in shade (Appendix 4A, Upr Childs, Red Dog, Full Sail, Anchor Stm., WhiteWash; 10-31 m): -3 to -33%; Range in change in 7DAD max. temp. (Appendices 2 (Powell, Savage), 3(Long Tom, RoundAgain, SingleShot, & 4B (Powell, RedDog, AnchorStm, Grisdale, Miller Pt.) : +1.0 to +8.3 °C	X	X

ID*	Study	Location (Georegion/# of sites) <sup>†</sup>	Pub. type <sup>a</sup>	Rel.? <sup>Δ</sup>	Buffer Prescriptions <sup>±</sup>	Conf. Sc. <sup>**</sup>	Effectiveness data (location of data within a publication, method of extraction if applicable) <sup>††</sup>	Measurements	
								Temp.	Shade
X <sub>5</sub>	Wilk et al., 2010	WA (Coast Ranges)	PR	N	7 no-cut buffers (33-49 ft.; 10-15 m); 3 patch buffers	10	Difference in canopy closure (Table 1): no- cut: -9%; patch buffers (average of patch (cut) and patch (leave) since same sites): - 45%		X
Y <sub>1</sub>	Zwieniecki and Newton, 1999	OR (CR/7, I/4)	PR	Y	6 standard FPA prescriptions; 5 hardwood conversions (HWCs); 3 HWCs limiting openings on south side of streams	6.5	For all prescriptions, no stat.sig. difference in shade; changes in temperature (differences between top and bottom of unit, averaged per prescription, from Fig.3 <sup>±±</sup> FPA: +1.3°C; HWC: +1.3 °C; S-sided HWC: +0.5 °C	X	X

\*Relates publications to ID for graphing purposes. Publications with the same subscript are from the same study (see Table 4).

<sup>†</sup> For studies located in Oregon, the Oregon Department of Forestry Geographic Regions (per OAR 629-635-0220) in which studies were completed is listed in parentheses, along with the associated number of sites included in this review; Geographic Regions: CR=Coast Range; I=Interior; WC=West Cascades; no data were collected in South Coast and Siskiyous Geographic Regions. Blue Mountains and East Cascades Geographic Regions are not listed because they were outside the region considered in this review.

<sup>a</sup> Gov't.=government report (including OSU research papers not published in peer-reviewed journal); PR=peer-reviewed; IR=in review.

<sup>Δ</sup> Is the study's objective or questions directly relevant to this review's question? Y = yes, N = no.

<sup>±</sup>All forest harvests outside of buffers are clearcuts, except those of Danehy et al. (2007) which were thinned from 200-300 down to 80 trees per acre.

<sup>\*\*</sup>Confidence score is a metric of the quality of a study (ranging from 4-12), with its calculation listed in a footnote of Table A.6.3.

<sup>††</sup>In this column, references to tables and figures are those of respective studies, not this report.

<sup>ω</sup>While other prescriptions were studied, they were not included in the analysis because of lack of adequate controls. Also note that data collected more than 5 years after harvest were not included in this review.

<sup>ΔΔ</sup>Data from Dent (1995; p. 6).

<sup>±±</sup> Trendlines in Figure 3 of Zwieniecki and Newton (1999) are not used since the analysis method does not allow for deriving values that are similar enough to the other studies for comparison; note that their temperature data are not plotted in this report because the data are ostensibly the same as those of Dent and Walsh (1997), and the latter report those data in a table, whereas those of the Zwieniecki and Newton (1999) were determined by measuring directly from the publication figure.

**Table 3. Summary of publications: outcomes measured and study relevance to the primary review question.**

<b>High Relevancy</b>	<b>Temperature</b>	<b>Shade</b>	<b>Both</b>	<b>Total</b>
Government	1	5	4	<b>10</b>
Peer Review	4	1	4	<b>9</b>
In Review	2	-	-	<b>2</b>
<i><b>Sub-total</b></i>	<i><b>7</b></i>	<i><b>6</b></i>	<i><b>8</b></i>	<i><b>21</b></i>
<b>Low Relevancy</b>				
Peer Review	-	3	1	<b>4</b>
<b>Total</b>	<b>7</b>	<b>9</b>	<b>9</b>	<b>25</b>

### ***3.2.2 Study design variability***

The studies varied greatly in the inclusion of pre-treatment data, intensity of data collection and replication. For example, fourteen of the publications had pre-treatment data that could be used for analysis. Shade data collection efforts ranged from just a few points along a reach to measurements taken every 25 m. Temperature data collection efforts ranged from data collected during several days to several weeks, and reported measures were frequently seven-day maximums, means, minimums and diel fluctuations. However, not necessarily all of these parameters were reported in any given study. The number of replicates for a particular combination of Geographic Region and harvest prescription ranged from 1 to 22 for the studies. Several publications were most appropriately characterized as compilations of single stream case studies, as they lacked design principles that allowed proper statistical analysis across sites (Rashin et al., 1992; Dent and Walsh, 1997; Martin, 2004; Hunter, 2010).

Though there are 25 publications selected for review, several of the publications had overlapping studies and share data (Table 4). For example, all three of the publications by lead author Groom utilized the same temperature dataset from the same study, but explore different relationships. Similarly, Wilk et al. (2010) collected habitat data (including canopy cover) for wildlife and Janisch et al. (2012) focused on stream temperature response due to management. Other situations with shared study designs include reporting on shade in one publication and temperature in another (e.g. Jackson et al., 2001, 2007).

**Table 4. Publications with overlap of data, or same sites, from the same study.**

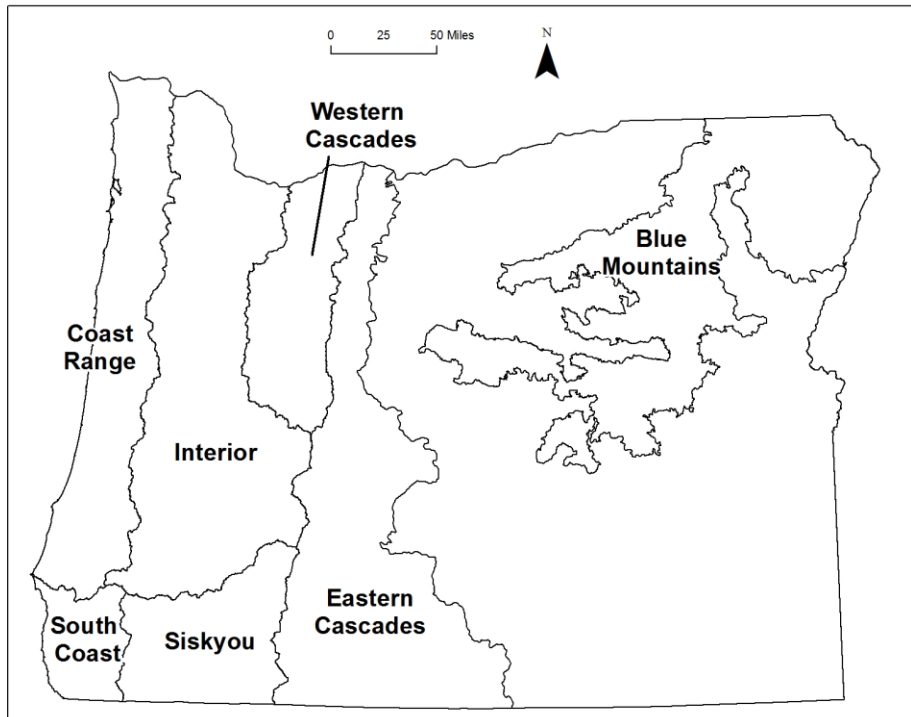
ID*	Study	Publications
1**	W. Oregon	Dent and Walsh, 1997; Zwieniecki and Newton, 1999
2	BC	Gomi et al., 2006; Kiffney et al., 2003
3	RipStream	Groom, 2013; Groom et al., 2011a, 2011b
4	SW WA	Jackson et al., 2001, 2007
5	W. WA	Janisch et al., 2012; Wilk et al., 2010

\* For each set of studies, a number identifies it; these numbers are the subscripts which appear in Table 2 and Figures 2-15.

\*\* Newton and Cole (2013b) included or collected data from W. Oregon study, but these data were not included in this review because they were either collected more than 5 years post-harvest, or are not summarized in a usable manner.

### **3.3 Geographical ranges and physical settings**

Due to the selection criteria for this review, all publications were limited to areas within, or similar to Oregon, west of the Cascades Crest. These areas were selected due to their similarities in climate, vegetation, hydrology, and topography with those from the study (Groom *et. al*, 2011b) that initiated this rule analysis. Vegetation composition was generally dominated by Douglas-fir (*Pseudotsuga menziesii*), with sub-dominants such as red alder (*Alnus rubra*), big-leaf maple (*Acer macrophyllum*), and several conifer species. All but one of the publications chosen for the review had study sites west of the Cascades in Oregon, Washington and British Columbia, and many were set in multiple ODF Geographic Regions (per OAR 629-634-0220; Table 2, Figure 1). The remaining publication was conducted in southeast Alaska. Twelve publications had study sites in the Oregon Coast Range, two in the western Cascades and eleven in the Interior (i.e. most of the Willamette Basin and upper Umpqua Basin). Nine publications had sites in western Washington (five in the Coast Range, two in the Cascades, and two in both regions).



**Figure 1. Oregon Department of Forestry Geographic Regions.**

A secondary purpose of this systematic review is to inform the Board's decision on the geographic extent of the rule analysis process. Overall, most sites studied are located in the Coast Range (n=82), followed by Interior (n=47), and West Cascades (n=23); no data were found in the South Coast or Siskyou Geographic Regions. However, data are only comparable between Geographic Regions when a single study applies the same buffer prescription in more than one Geographic Region (comparison across studies requires analysis beyond the scope of this SR). Thus, there are fewer data available for comparison across Geographic Regions (15 combinations of temperature or shade data for specific rule prescriptions; Figures 2 and 3). Whereas data from publications are included in these comparisons regardless of their confidence score, it is worth noting:

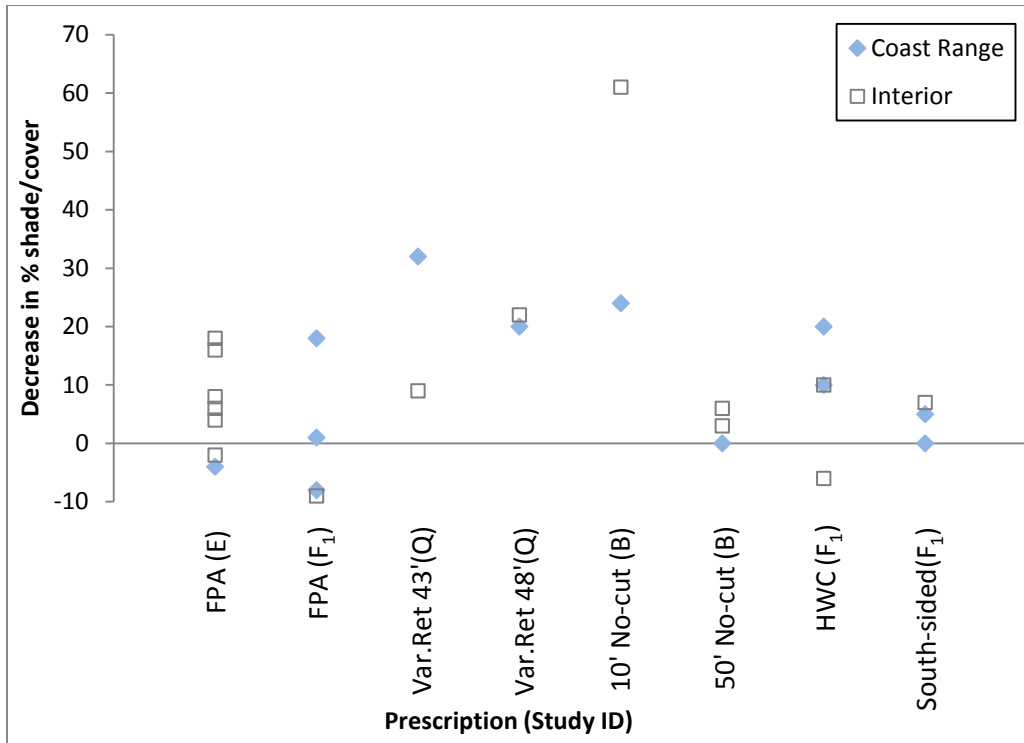
- Most comparisons are from studies with low confidence scores (<7);
- Although the Coast Range and Interior are the only Geographic Regions with sites from studies with high confidence scores ( $\geq 10$ ; n=31 and 5, respectively), only two sites from each Geographic Region are comparable with one-another; and,
- All of the Western Cascades sites are from studies with low confidence scores (< 7), and only one of these sites is comparable with those of another Geographic Region.

No clear picture emerges when comparing prescription effectiveness between Geographic Regions for any given study (Figures 2 and 3). This lack of clarity may be due to insufficient data with which to make robust comparisons since no comparison between Geographic Regions has more than two sites for each combination of buffer prescription, Geographic Region, and study. Additionally, existing data present no clear pattern. The Coast Range appeared to have greater change in shade or temperature for particular buffer prescriptions in seven comparisons with those of Interior, whereas the latter appeared to have greater change in shade or temperature in four comparisons (Figures 2 and 3). The remaining four comparisons of these two regions appeared to have similar changes in shade or temperature by buffer prescription. The only Western Cascades site assessed had the same increase in temperature as the associated Interior site, both of which were larger than that of the Coast Range site (Figure 3).

The finding of degradation by the Board was based on the results of the RipStream study, which largely focused on streams within the Coast Range Geographic Region. Results from non-RipStream studies included in this review indicate that exceedances of the PCW criterion also appear to occur<sup>1</sup> in the Interior Geographic Region for FPA buffers (Figure 3). Data are not available for other western Oregon Geographic Regions, or for the FMP buffer type that was also included in the RipStream study.

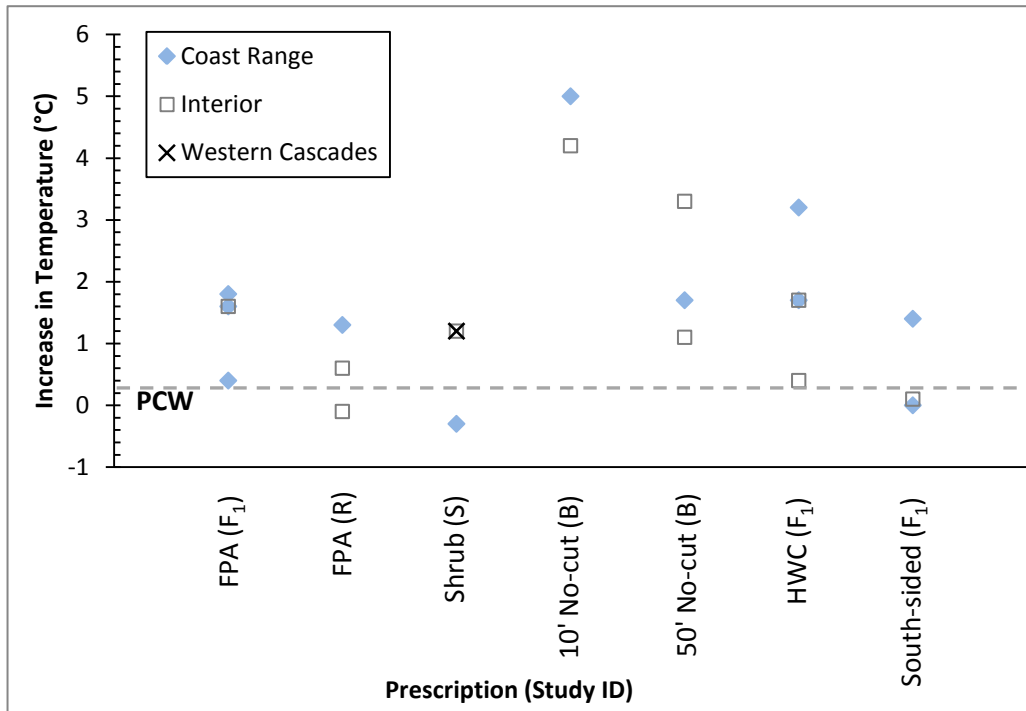
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<sup>1</sup> Note that to determine whether the PCW criterion is met, the study needs to be designed specifically to test the criterion. Only RipStream specifically tested for achieving the PCW criterion, thus the use of wording similar to “appeared to meet the PCW criterion” is used when discussing whether or not other studies met the PCW criterion since they did not test for it.



**Figure 2. Decrease in shade for combinations of Geographic Regions and associated buffer prescriptions.**

Each symbol represents data from one site for a particular rule prescription from a particular study (Appendix C). The symbol type denotes the ODF Geographic Region: blue diamonds are Coast Range sites, hollow squares are Interior sites. Prescriptions are: FPA = Forest Practices Act; Var.Ret = Variable Retention with 43 or 48 foot buffers; 10' and 50' are for No-cut buffers of 10 and 50 feet, respectively; HWC = hardwood conversion; South-sided = buffers retained on southern side of streams. Letters in parentheses denotes study ID (Table 2): E=Dent, 2001; F<sub>1</sub>=Dent and Walsh, 1997; Q= Morman, 1993; B=Brazier and Brown, 1973.



**Figure 3. Increase in temperature for combinations of Geographic Regions and associated buffer prescriptions.**

Each symbol represents data from one site for a particular rule prescription from a particular study (Appendix C). The symbol type denotes the ODF Geographic Region: blue diamonds are Coast Range sites, hollow squares are Interior sites, and “X” is a Western Cascades site. Prescriptions are: FPA = Forest Practices Act; Shrub = shrub shade; 10’ and 50’ are for No-cut buffers of 10 and 50 feet, respectively; HWC = hardwood conversion; South-sided = buffers retained on southern side of streams. Letters in parentheses denotes study ID (Table 2): F<sub>1</sub>=Dent and Walsh, 1997; R=Newton and Cole, 2013a; S=Newton and Cole, 2013b; B=Brazier and Brown, 1973. The dashed line labeled PCW is the Protecting Cold Water criterion.

### 3.4 Measurements

The primary systematic review question focuses on two factors associated with protecting core cold water habitat: 1) stream temperature and 2) riparian shade. Of the twenty-five publications reviewed, seven included only measurements of stream temperature, nine included only measures of riparian shade, and nine included measures of both stream temperature and riparian shade (Table 3). Stream temperature is a water quality parameter that can be measured directly using a number of sensing technologies: most commonly a thermometer, recording thermograph (a thermistor coupled with a data logging device), or, recently, fiber optics. Contrastingly, shade is difficult to measure directly because, for any given location, it changes

both throughout the day and seasonally as a function of the position of the sun. Researchers have overcome this problem by using various measures of canopy density or light as proxies for shade (Davies-Colley and Payne, 1998).

All of the systematic review papers reporting stream temperature results collected time series of data measured at sub-daily intervals with recording thermographs. The duration of temperature data collection ranged from as little as two weeks (Rashin, 1992) during the critical summer low flow period to year-round (Gomi et al., 2006; Kiffney et al., 2003). Measurement accuracy varied across studies for papers that actually reported such values, ranging from  $\pm 0.2$  to  $\pm 1.0$  °C. Resolution was only reported by Janisch et al. (2012) who had one sensor type with resolution of  $\pm 0.16$  and another with a resolution of 0.5 °C. As a frame of reference, most current sensors are advertised with  $\pm 0.2$  °C accuracy and 0.02 °C resolution.

Overhead canopy cover was measured with either a spherical densiometer (Dent, 2001; Dent and Walsh, 1997; Martin, 2004; Morman, 1993; Schuett-Hames et al., 2012; Veldhuisen and Couvelier, 2006; Zwieniecki and Newton, 1999) or via hemispherical photography (Allen and Dent, 2001; Dent and Walsh, 1997; Groom et al., 2011b; Hunter, 2010; Janisch et al., 2012; Wilk et al., 2010), whereas oblique canopy cover or angular canopy density (ACD) was measured with an angular canopy densiometer (Brazier and Brown, 1973; Steinblums et al., 1984). Despite the spherical densiometer being the most common device used to measure canopy cover, measurements obtained are subject to user-bias (Davies-Colley and Payne, 1998). Hemispherical photography is a less subjective means for quantifying canopy cover. However, multiple methods were used to analyze the photographs making direct comparison of results across studies difficult. Allen and Dent (1997), Groom et al. (2011a), and Hunter (2010) report hemispherical photography results as a Global Site Factor (GSF), the ratio of direct and diffuse energy at the point of the photograph to the total available direct and diffuse energy for that latitude, longitude, and day of year. Janisch et al. (2012) reports Canopy and Topographic Density (CTD), a metric that, as its name implies, takes into account both the density of the canopy and the topographic obscurance. Wilk et al. (2010) present the photographic analysis from the same study only as a percent canopy cover.

Photosynthetically active radiation (PAR; Kiffney et al., 2003) and solar insolation (Brosofske et al., 1997; Danehy et al., 2007) are both measures that describe the amount of light

reaching a certain point. Direct measures of light are sensitive to subtle changes in cloud cover and the position of the sun, a factor that was considered when evaluating the robustness of outcome measures of light reported by Broszofsky et al. (1997) and Kiffney et al. (2003). Danehy et al. (2007) estimated total solar insolation indirectly using hemispherical photography.

Reporting of measurement accuracy and resolution, for both temperature and shade, was inconsistent across studies. Therefore, systematically incorporating this uncertainty into the summary plots created as a part of this SR was not feasible. The reader is thus cautioned to keep this source of uncertainty in mind when evaluating actual values of stream temperature and shade extracted as a part of this systematic review (when reported in the publication, we included accuracy and resolution data in Completed Table A.6.2 of Appendix B).

The secondary review question focused on how effects modifiers interact with near-stream forest management. In order to properly evaluate the influence of a particular effects modifier, formal inclusion in the statistical analysis of a publication was necessary. The most commonly evaluated effects modifiers were the length and width of the riparian management area, stream width and depth, and stream gradient (Table 5). A number of publications presented data for variables that likely acted as effects modifiers without actually assessing their influence statistically; most frequently, the types of trees, tree density, and stream/watershed aspect were reported but not evaluated (Table 5). In general, there was a lack of consistency in assessing effects modifiers across studies. This point is highlighted by the large number of effects modifiers that were assessed in only one, two, or three studies and the fact that the most often assessed modifier (length, width of riparian reserve) was only addressed in approximately one-third of the reviewed studies. Since the main purpose of the SR was to test outcomes for temperature associated with shade, fully addressing the effects modifiers would require a more extensive analysis that is beyond the scope of this report.

**Table 5. Information on effects modifiers addressed in publications.**

First two columns list effects modifiers statistically analyzed for the respective measure (i.e., column heading); number of publications for each effects modifier listed in parentheses. Effects modifiers from the protocol (Appendix A) that are not listed were not considered in any publications.

<b>Temperature</b>	<b>Shade</b>	<b>Measured &amp; Reported but not used in analysis</b>
Length, width of riparian reserve (7)	Length, width of riparian reserve (10)	Types of trees (5)
Gradient (7)	Stream width/depth (6)	Tree density (5)
Stream width/depth (6)	Other riparian vegetation (5)	Aspect (5)
Aspect (4)	Gradient (5)	Tree/basal area retention (4)
Harvest on both or single sides of riparian reserve (4)	Discharge (3)	Time since harvest (4)
Canopy cover (4)	Substrate (3)	Discharge (4)
Discharge (3)	Aspect (3)	Length, width of riparian reserve (3)
Elevation (3)	Types of trees (2)	Logs or slash left in stream (3)
Air temperature (3)	Tree/basal area retention (2)	Windthrow (3)
Time of year (2)	Harvest on both sides or single side of riparian reserve (2)	Continuity of flow (3)
Substrate (2)	Logs or slash in stream (2)	Gradient (3)
Time since harvest (2)	Elevation (2)	Other riparian vegetation (2)
Types of trees (1)	Tree harvest in part of riparian reserve (1)	Canopy cover (2)
Residual stand composition (1)	Tree height, age (1)	Groundwater-surface water interactions (2)
Tree/basal area retention amount (1)	Crown height (1)	Elevation (2)
Other riparian vegetation (1)	Windthrow (1)	Air temperature (2)
Clearcut vs. thin (1)	Distance from stream source (1)	Tree height, age (1)
Distance from stream source (1)	Groundwater-surface water interactions (1)	Crown height (1)
Groundwater-surface water interactions (1)	Geology and soils (1)	Residual stand composition (1)
Flow through/from a wetland (1)	Time of year and season (1)	Method of tree removal (1)
	Air temperature (1)	Stream width/depth (1)
		Substrate (1)
		Geology and soils (1)

### **3.5 Variations in Statistical Analyses**

Methods for analyzing temperature varied widely among the studies, depending on the study design and measures selected for study. The majority of temperature studies included some type of statistical analysis of data, primarily analysis of variance (ANOVA) if differences between groups were considered by separating samples into groups prior to analysis (e.g. Dent and Walsh, 1997; Danehy et al., 2007), and regression analysis if the goal was to directly account for the effects of modifiers (e.g. Jackson et al., 2001; Veldhuisen and Couvelier, 2006; Groom et al., 2011b). A few of the studies used the measured data to develop predictive models to explore the importance of multiple effects modifiers, such as in Groom et al. (2011a,b; 2013) and Veldhuisen and Couvelier (2006). Autocorrelation of temperature time series data was addressed, but not consistently among the studies, which affected their statistical robustness score (Completed Table A.6.3).

Methods for analyzing shade were more consistent, with most of the studies conducting simple statistical tests of differences between both a control and the buffer type(s). The exception tended to be if studies had too few samples for a statistical comparison or only presented results graphically for comparison (e.g. Rashin et al., 1992; Martin, 2004; Hunter, 2010). For shade and cover studies, a sample was considered a control if it was collected pre-treatment or at a similar landscape unit at a nearby location.

### **3.6 Rule Alternatives**

Each reviewed paper was rated for relevance to the sixteen rule alternatives proposed by the Board (Completed Table A.6.4). Seven of the sixteen rule alternatives had at least one highly relevant study (i.e., provides quantitative data that addresses the effectiveness of a particular prescription of a rule alternative at protecting stream temperature or shade), whereas nine rule alternatives had no studies that were highly relevant to them (Table 6). Since these latter alternatives lack geographically-relevant evidence, they are not discussed further. Several publications were highly relevant to more than one rule alternative: 14, 8, and 3 publications were highly relevant to 1, 2, and 3 different rule alternatives, respectively. All rule alternatives had at least one study of low relevance.

In the following sub-sections, rule alternatives with highly relevant studies are discussed with respect to the range of variation in metrics defining each alternative, the range of variation

in outcome measures, the degree of effectiveness at protecting against increases in stream temperature or decreases in riparian shade, and the overall confidence in the findings. Where applicable, the role of effects modifiers in influencing effectiveness is also addressed.

**Table 6. Total number of studies of high relevance to each rule alternative.**

A study is considered highly relevant if it provides quantitative data that addresses whether or not a particular design or prescription of a rule alternative is effective at preventing warming or maintaining shade. See Table A.5.1 for description of each rule alternative, and Completed Table A.6.4 for details of which studies were highly relevant to which rule alternatives.

	Current FPA	State Forests Standards	Derived variable retention	Large tree variable retention	Minimize gaps	Basal area retention by aspect	Field-based shade standard	Shade approach from W/A DNR method	Shrub shade	Hardwood sites	Hardwood shade	Derived no-cut buffer	No-cut aspect buffers	Oregon Plan	Plan for alternate practice	One-sided buffer
Total # studies (pubs) *	4 (7)	1 (3)	2	0	0	0	0	0	1	0	0	12 (15)	0	0	7 (10)	1 (2)

\*Sum of all studies that are highly relevant for each rule alternative; parentheses indicates the total number of publications relevant to a particular alternative if different than the number of studies. See Table 4 for clarification of relationship between studies and publications.

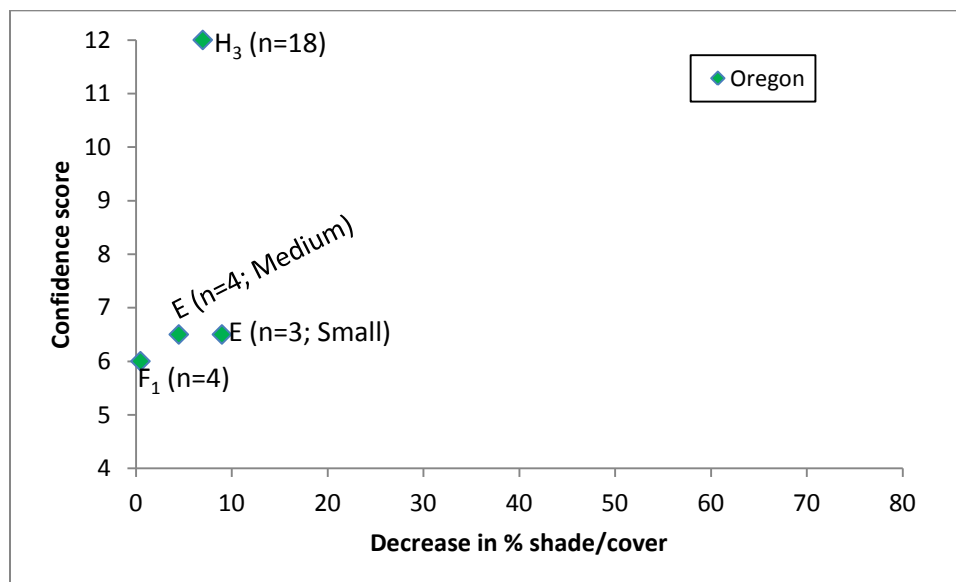
### 3.6.1 Forest Practices Act (FPA)

Description of rule alternative: FPA is a specific prescription of a variable retention buffer: no cutting is allowed in the first 20 feet from the high water level, with the remainder of a riparian management area (RMA) extending to different widths depending on stream size (small, medium, large) and type (fish, domestic use, non-fish). For the portion of the RMA outside the 20-foot no-cut zone, limited harvest is allowed (Oregon Department of Forestry, 2010).

Seven publications covering four different studies were rated as highly relevant to describing changes in temperature and/or shade with harvest using FPA buffer management practices; nine publications were determined to have low relevance (Completed Table A.6.4). In some cases, clearcut harvesting outside of the buffers occurred on both sides of the stream, but there were also cases where there was harvest on just one side of the stream. Requirements for

tree retention within the RMAs differs based on ODF Geographic Region, and though the majority of study sites were in the Coast Range, there were also sites in the Interior for all studies except for Allen and Dent (2001).

All studies reported an average decrease in shade or cover in the range -0.5% to -9%; (Figure 4) as a result of FPA management practices, regardless of whether it was a small or medium stream (Dent and Walsh, 1997; Dent et al. 2001; Groom 2011a). Confidence in study design was low for the Dent and Walsh (1997) and Dent et al. (1999) studies, primarily due to low number of sites resulting in an inability to make robust statistical comparisons of the results. Due to the nature of the data collection method, there can be considerable error, and thus variability, in these measures leading to a wide range in results. Therefore, it is even more important to have larger sample sizes, and thus a decrease in shade of 0.5% as interpreted from Dent and Walsh (1997) should be considered inconclusive.

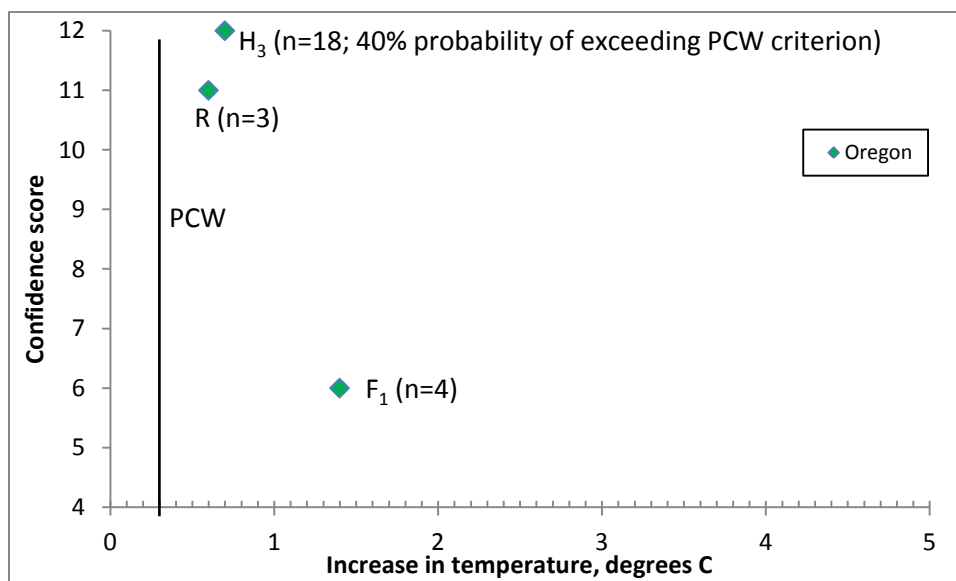


**Figure 4. Decrease in shade for sites with FPA buffers.**

Letter refers to publication ID (Table 2), n is the number of sites, and Small and Medium refer to stream size as defined in the FPA. Data from X- and Y-axes are listed in Table 2<sup>2</sup>.

<sup>2</sup> Buffer effectiveness data, and associated confidence in these data, are illustrated in Figures 4-15. A study's buffer prescription is more effective at protecting cold water or shade when its X-axis data (i.e., change in shade/cover or temperature data) are closer to zero. The quality of the study from which these data were obtained is plotted on the Y-axis: the better the study, the higher its confidence score; note that the range of scores (4 to 12) spans the entire range of possible confidence scores.

Increases in temperature were also observed for all relevant studies, though the amount of increase varied (Figure 5). Groom et al. (2011a) and Newton and Cole (2013a) reported temperature increases of 0.7 °C and 0.6 °C, respectively, and there is high confidence that their results provide reliable information. Those publications with lower confidence in reported results had higher increases in their temperature: 1.3 °C (Zwieniecki and Newton, 1999) and 1.4 °C (Dent and Walsh, 1997; note that these two publications report the same data though reduced and analyzed differently; only data from Dent and Walsh, 1997 are plotted). In all cases, the increase in temperature appeared larger than the PCW criterion. Groom et al. (2011a) found large variation in temperature responses, ranging from -0.9 to 2.4 °C, and thus there is evidence that not all observed streams experienced an increase in temperature. Groom et al. (2011b; 2013) explored the probability of exceeding stream temperature criteria. The chance of a site managed using FPA rules exceeding the PCW criterion between a pre-harvest year and a post-harvest year was 40%, and 7 out of 18 sites exceeded the 16 or 18 °C criteria for salmonids (only 4 of the 18 sites exhibited a potential harvest signal in that they did not exceed pre-harvest but did exceed post-harvest; 2 of the 4 sites had exceeded upstream of the study reach pre-harvest).



**Figure 5. Increase in temperature for sites with FPA buffers.**

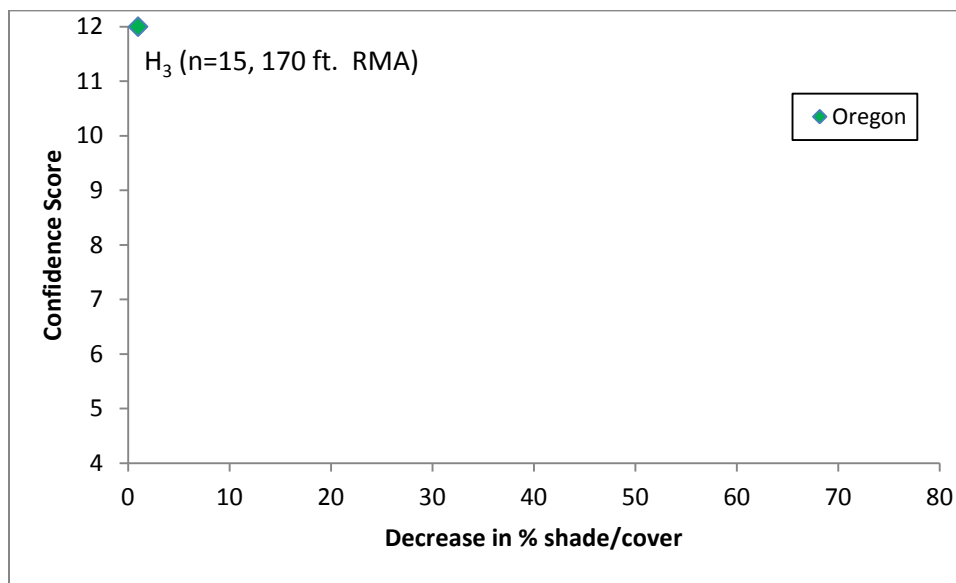
Letter refers to publication ID (Table 2), n is the number of sites, PCW is the Protecting Cold Water criterion, and Small and Medium refer to stream size as defined in the FPA. Data from X- and Y-axes are listed in Table 2.

### 3.6.2 State Forest Management Plan (FMP)

*Description of rule alternative:* FMP is a specific prescription of a variable retention buffer: no cutting is allowed in the first 25 feet from the high water level, with the remainder of the riparian RMA extending to different widths depending on stream size (small, medium, large) and type (fish, domestic use, non-fish). For the portion of the RMA outside the 25-foot no-cut zone, limited harvest is allowed (Oregon Department of Forestry [ODF], 2001).

Three publications from one study (RipStream) contained highly relevant results of temperature and/or shade using buffer rules from the State Forest Management Plan (FMP; Groom et al. 2011a,b, Groom et al. 2013); eleven publications were determined to have low relevance (Completed Table A.6.4). The highly relevant study had 15 sites, set in the Oregon Coast Range and Interior Geographic Regions; therefore, all samples are from small and medium streams in a geographically similar area.

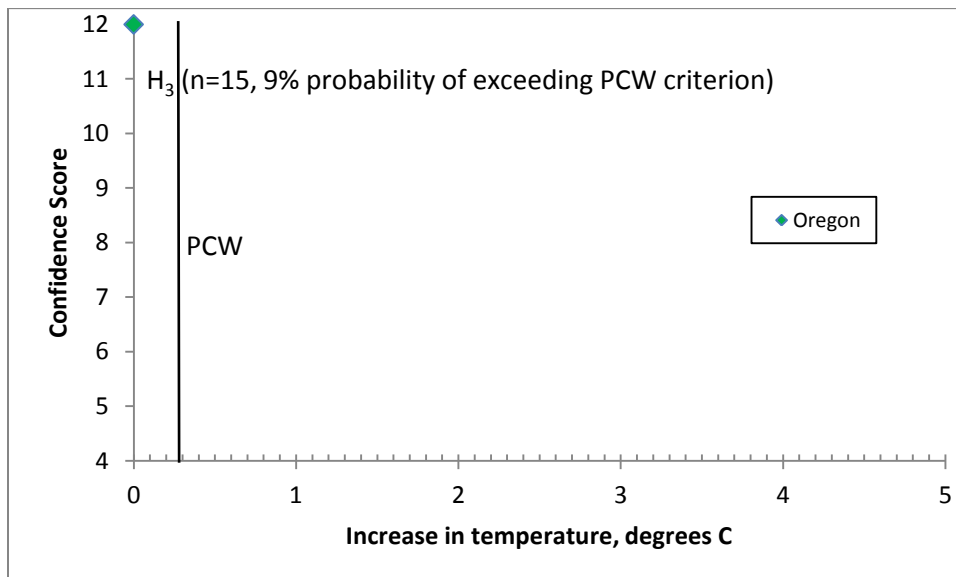
Shade comparisons were made pre- and post-harvest and there was no detectable change in shade post-harvest from pre-harvest conditions (Figure 6; mean decrease of 1%, n=15, p = 0.269, Groom et al., 2011a). Shade pre- and post-harvest was between 80-95% for all sites.



**Figure 6. Decrease in shade for sites with FMP buffers.**

Letter refers to publication ID (Table 2), n is the number of sites, and 170 ft. is the one-sided RMA (riparian management area) width. Data from X- and Y-axes are listed in Table 2.

Findings from this study suggest there also are little to no noticeable changes in temperature using FMP practices (Figure 7). Changes in temperature were reported by looking at both change in temperature and probability of exceedances of criteria. Change in temperature at FMP sites averaged 0.0 °C, although there was large variability in these changes as evidenced by the range of -0.9 to +2.3 °C (Groom et al, 2011a). The chance of exceeding the 0.3 °C PCW criterion was found to be 9% and not statistically different from zero<sup>3</sup>. Of the 15 sites, none exceeded the 16 °C or 18 °C criteria (Groom et al, 2011b; 2013). Strengthening the confidence in the results, data analysis for this study included measurement of effects modifiers (e.g., discharge, length and width of the reserve, characteristics of the stand, landscape position and air temperature), and thereby taking into consideration a number of factors that have a high likelihood of influencing stream temperatures.



**Figure 7. Increase in temperature for sites with FMP buffers.**

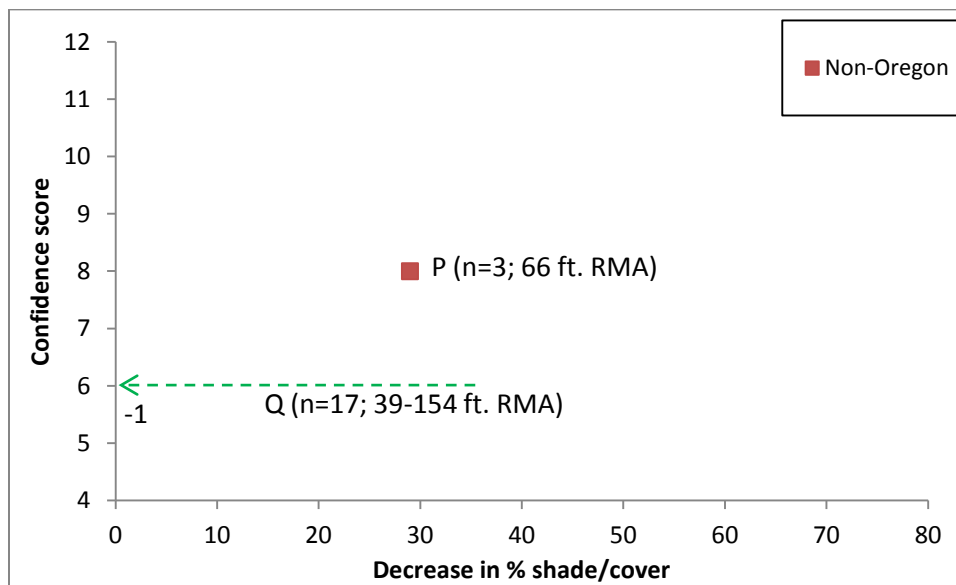
Letter refers to publication ID (Table 2), n is the number of sites, 170 ft. is the one-sided RMA (riparian management area) width, and PCW is the Protecting Cold Water criterion. Data from X- and Y-axes are listed in Table 2.

<sup>3</sup> Note that from a regulatory perspective, achievement of the PCW criterion is evaluated with respect to a group of sites, and thus a site might not meet the criterion but the entire group of sites could still be considered to achieve it.

### 3.6.3 Derived Variable Retention

*Description of rule alternative:* This alternative allows spatially-variable harvest intensity determined by e.g., the density of stems, basal area, or other stand metric required to be left within a specific locale or zone of the RMA.

Two studies were highly relevant to the variable retention buffer rule alternative (in addition to the FPA- and FMP-related studies not included in this part of the discussion). Morman (1993) evaluated canopy density for seventeen variable retention buffers ranging from 25 to 100 feet in width in the Coast Range and Interior Geographic Regions. Martin et al. (2004) measured stream temperature and riparian shade for three sites with 25-foot no-cut buffers and an additional 41-foot width of partial cut buffer in southeastern Alaska. However, the stream temperature control site was compromised, so only the shade data is considered in this synthesis. Six studies were considered to have low relevance to this rule alternative.



**Figure 8. Decrease in shade for sites with variable retention buffers.**

Letter refers to publication ID (Table 2), n is the number of sites, distance is the one-sided RMA width. Dashed line indicates a range of outcomes for sites for which averaging is inappropriate (e.g., due to different buffer widths), with arrow head and accompanying number indicate range extended beyond X-axis. Data from X- and Y-axes are listed in Table 2.

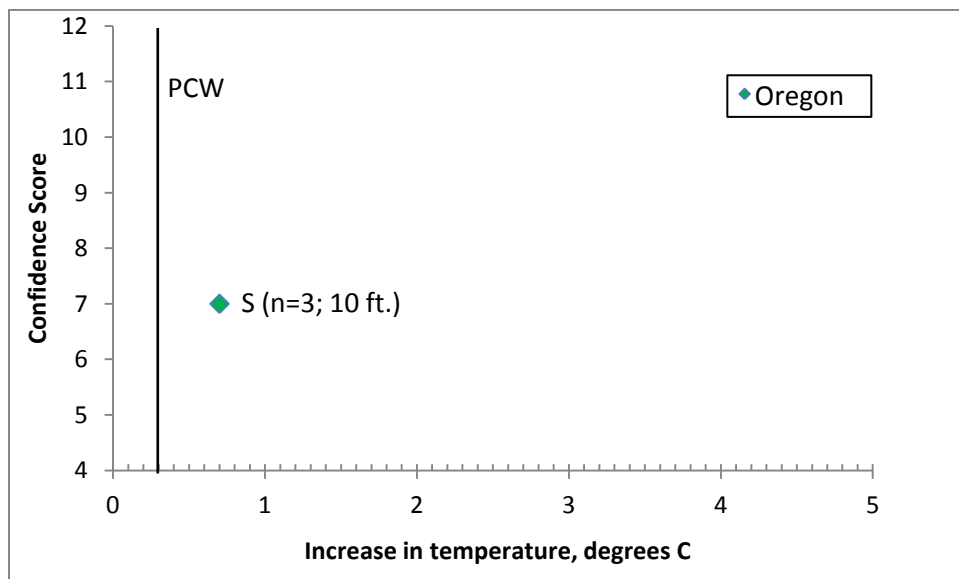
Both studies showed a decrease in shade where variable retention buffers were applied (Figure 8). Martin et al. (2004), who had a low sample size but a relatively sound study design, measured an average canopy density decrease of 29%. Morman (1993) used a larger sample size

(17 sites) and found an average decrease of 19% (range: +1 to -35%). Morman's study evaluated the role of aquatic area width and hardwoods versus conifers in relation to the amount of shade provided. However, despite the significantly larger sample size and assessment of effects modifiers, the confidence in the Morman study is lower than that of Martin et al. (2004; Figure 8). Additional data is required to definitively assess the effectiveness of this prescription at protecting stream shade.

### 3.6.4 Shrub Shade

*Description of rule alternative: This alternative considers the contribution of shade from shrubs to protect cold water.*

Newton and Cole (2013b) provided highly relevant results for Shrub-shade management practices by examining “no-tree buffers”. In their study, different management practices were instituted along a length of stream where harvested and unharvested blocks lie adjacent to each other along the length of channel. Widths of RMAs ranged from 15 to 70 feet, depending on stream width, and were interspersed with no-tree buffers along a harvested reach 600 feet long. Although harvest was conducted so that damage to shrubs was minimized, it is possible that there were locations within the buffer without shrub shade. Only the upstream-most treatment was considered for this review due to inadequate controls on downstream reaches.



**Figure 9. Increase in temperature for sites with shrub shade buffers.**

Letter refers to publication ID (Table 2), n is the number of sites, distance is the width of leaving shrubs, and PCW is the Protecting Cold Water criterion. Data from X- and Y-axes are listed in Table 2.

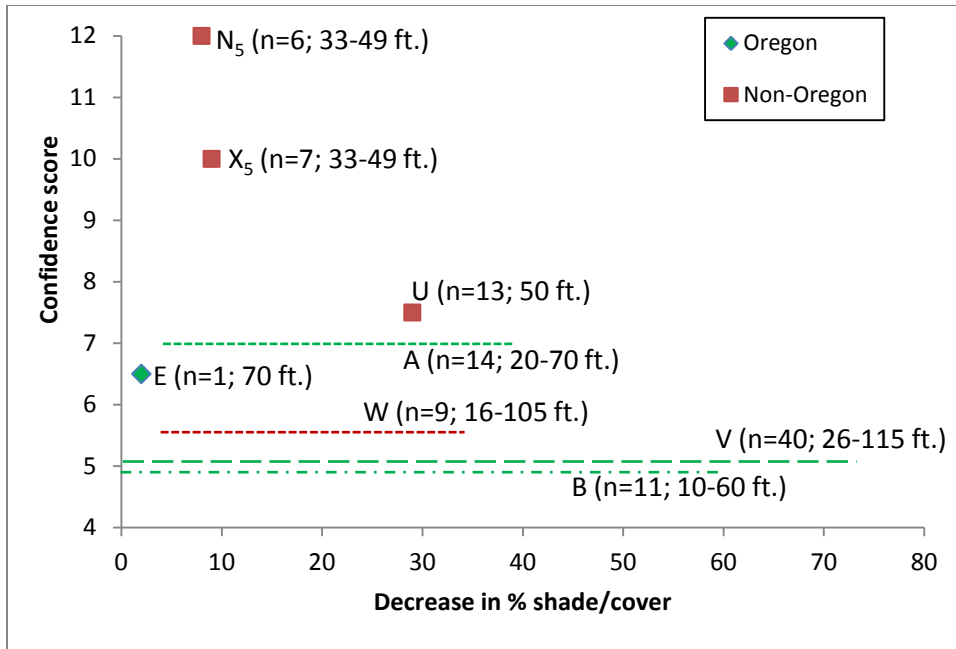
Stream temperature differentials increased in the no-tree buffers by an average of +0.7 °C (Figure 9; range: -0.3 to +1.2 °C) post-harvest (Newton and Cole 2013b). Effects considered when analyzing data include stand characteristics and some landscape characteristics, though sample sizes were low and analysis focused on differences by site and year.

### **3.6.5 Derived No-cut Buffer**

*Description of rule alternative: This rule alternative prescribes no cutting of trees within a specific distance of the stream.*

The no-cut buffer was the most frequently studied rule alternative: twelve studies (fifteen publications) were rated as highly relevant and an additional four publications had low relevance (Completed Table A.6.4). Of the highly relevant publications, eight presented data on riparian shade, three presented data on incoming solar radiation, and seven included stream temperature data. Four of the nine highly relevant riparian shade publications presented data collected in Oregon (Allen and Dent, 2001; Brazier and Brown, 1973; Dent, 2001; and Steinblums et al., 1984). However, only one of the seven stream temperature publications presented data collected in Oregon (Brazier and Brown, 1973).

No-cut buffer widths in highly relevant riparian shade studies ranged from 7 to 115 feet per side (Figure 10; Table 1). The effectiveness of the no-cut buffer in preventing an increase in shade varied considerably. The two publications with the highest confidence score, Janisch et al. (2012) and Wilk et al. (2010), found that a continuous buffer, ranging from 33 to 49 feet (10 to 15 m), resulted in a 10% decrease in canopy density (both publications originated from the same study). Similarly, Schuett-Hames et al. (2012) measured an average canopy density reduction of 12% across thirteen 50-foot no-cut buffers in western Washington.



**Figure 10. Decrease in shade for sites with no-cut buffers.**

Letter refers to publication ID (Table 2), n is the number of sites, and distance is the no-cut buffer width. Dashed lines indicate a range of outcomes for sites for which averaging is inappropriate (e.g., due to different buffer widths). Data from X- and Y-axes are listed in Table 2.

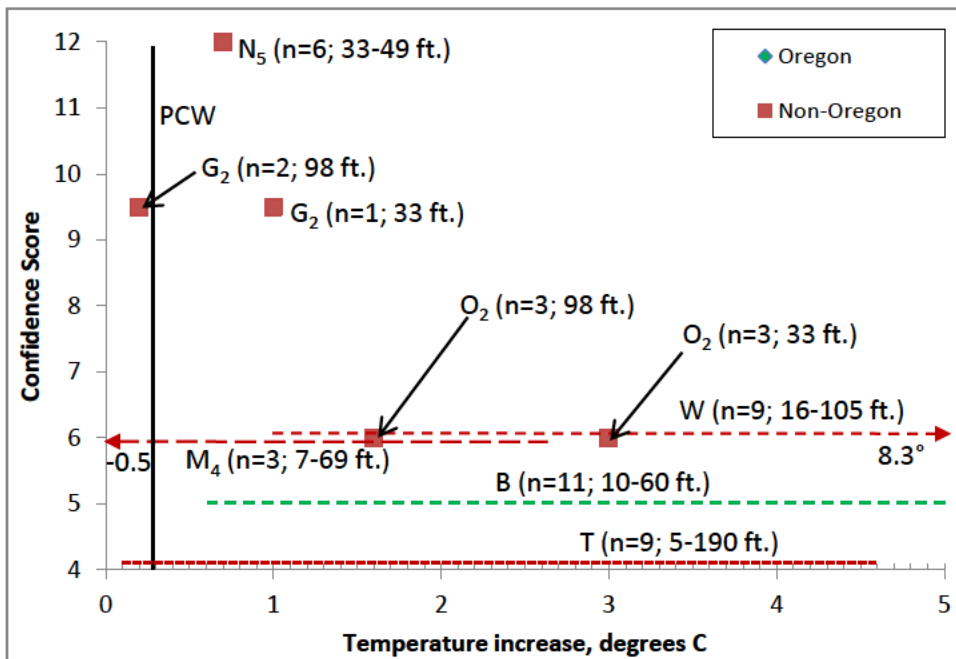
Several studies included multiple buffer widths in their assessment of riparian shade (Allen and Dent, 2001; Brazier and Brown, 1973; Jackson et al., 2007; Steinblums et al., 1984; Veldhuisen and Couvelier, 2006). A positive relationship between angular canopy density and buffer width was evident in the data of both Brazier and Brown (1973) and Steinblums et al. (1984) despite considerable variability amongst the responses at individual measurement locations. Contrastingly, no strong positive relationship between canopy density and no-cut buffer width was visually evident in the data presented by Allen and Dent (2001; no regression performed for no-cut data only) or Veldhuisen and Couvelier (2006). Jackson et al. (2007) caution against use of their canopy cover data because of concern that the survey reach was not necessarily representative of the entire stream; therefore, their results are not included in this assessment (see Completed Table A.6.2 for results).

Three studies evaluated buffer effectiveness based on a change in solar insolation (solar insolation results are not included in Figure 10 because units are not directly relatable to percent

shade). Kiffney et al. (2003) found that photosynthetically active radiation was approximately 5-times greater in the 33-foot buffer than in the 98-foot buffer. Brosofske et al. (1997) found a logarithmically-decreasing relationship between solar insolation and buffer widths ranging from 26 to 141 feet ( $r^2=0.60$ , inclusive of control sites;  $n=18$ ). Danehy et al. (2007) measured the difference in solar insolation between uncut control streams and streams with 49-foot no-cut buffers surrounded by thinned harvest units upslope (as opposed to clearcuts for the rest of the studies). Based on the large variability in control measurements ( $95 \pm 89 \text{ MJ/m}^2/\text{day}$ ;  $n=6$ ), the difference in the Danehy et al. (2007) control and treatment is considered negligible (treatment =  $137 \pm 28 \text{ MJ/m}^2/\text{day}$ ;  $n=7$ ). Caution is suggested in considering these results as it is difficult to relate insolation values to protection of stream shade based solely on the data provided in these studies.

No-cut buffer widths in highly relevant stream temperature studies ranged from 5 to 190 feet and, as with the riparian shade studies, responses to treatment were highly variable (Figure 11; Table 2). Four publications reported results where the temperature response to a no-cut buffer appeared to meet the PCW criterion: the 98-foot buffer of Gomi et al. (2006), two sites of Janisch et al. (2012), one site of Rashin et al. (1992), and one of the 26- to 33-foot buffers of Jackson et al. (2001; note that data from these latter two could not be meaningfully averaged due to the large range of buffer widths). It should be noted that Danehy et al. (2007) measured temperature within the substrate and thus these data are not included in the review, and the Jackson et al. (2001) stream was significantly covered by blowdown. Gomi et al (2006) and Janisch et al. (2012) found that 33-foot and 33- to 49-foot no-cut buffers, respectively, resulted in an about a 1 °C increase in temperature over the study reach (these studies had the two highest confidence scores) while the 33-foot buffer of Kiffney et al. (2003) resulted in a 3 °C increase (a 1.5 °C increase was reported for their 98-foot buffer). Note that the discrepancy in temperature results between Kiffney et al. (2003) and Gomi et al. (2006), which report on the same study, is a result of the latter using a longer post-treatment data record in their analysis (1 year versus 4 years). Veldhuisen and Couvelier (2006) reported the largest temperature increase of all the highly relevant studies, an 8.3 °C increase in the maximum value of the 7-day moving mean of the daily maximum (buffer width unknown; it should also be noted that the forested controls had upstream-to-downstream increases ranging from +1.0 to +2.7 °C during the same monitoring

period). The eleven sites of Brazier and Brown (1973) had a modest inverse relationship between temperature response and buffer width. The smallest differences in upstream-to-downstream temperature change (no information was provided on the exact temperature metric presented) were for a 60-foot and a 100-foot buffer (both had a 0.6 °C increase); however, one of the 100-foot no-cut buffers had a measured increase of 2.2 °C (note that although Brazier and Brown (1973) received a relatively low confidence score, the temperature and buffer width data assessed here are considered robust).



**Figure 11. Increase in temperature for sites with no-cut buffers.**

Letter refers to publication ID (Table 2), n is the number of sites, distance is the no-cut buffer width, and PCW is the Protecting Cold Water criterion. Dashed lines indicate a range of outcomes for sites for which averaging is inappropriate (e.g., due to different buffer widths) dashed lines with arrow heads and accompanying number indicate range extended beyond X-axis. Data from X- and Y-axes are listed in Table 2.

The publications reviewed showed that while no-cut buffers have the potential to protect against exceeding the PCW criterion, the generally implied notion that wider buffer widths provide better protection is not fully supported by all studies. For example, five studies showed greater protection of temperature or shade with wider buffers (Brazier and Brown, 1973; Kiffney et al., 2003; Gomi et al., 2006; Steinblums et al., 1984 Veldhuisen and Couvelier, 2006; note that

the strength of relationship between level of protection and buffer width was variable amongst these studies) whereas Allen and Dent (2001) showed no relationship between buffer width and protection. The large degree of variability in the findings across publications means there would be uncertainty when specifying a no-cut buffer width, based on these data, that would achieve the PCW criterion. The variability in magnitude of response is presumably related to the confounding role of effects modifiers in combination with the various buffer width treatments.

Unfortunately, there was no consistency in evaluation of effects modifiers between studies. Janisch et al. (2012) found a significant correlation between mean daily temperature response and elevation, catchment area, aspect, channel gradient, channel length, depth, canopy + topographic density (CTD), and percent of catchment with wetland. Veldhuisen and Couvelier (2006) also found significant relationships between temperature response and elevation and channel gradient plus percent shade (however, their effects modifiers analysis included fully forested, clearcut, and debris flow streams). Several of the highly relevant publications reported temperature results from studies conducted in first-order, non-fish-bearing streams (Jackson et al., 2007; Janisch et al., 2012; Veldhuisen and Couvelier, 2006). Controls on water temperature in the extreme headwater reaches of a stream network are more variable than the dominant controls in larger downstream reaches (Jackson et al. 2007; Janisch et al, 2012), a factor that likely added to the variability in the response to treatment for this rule alternative.

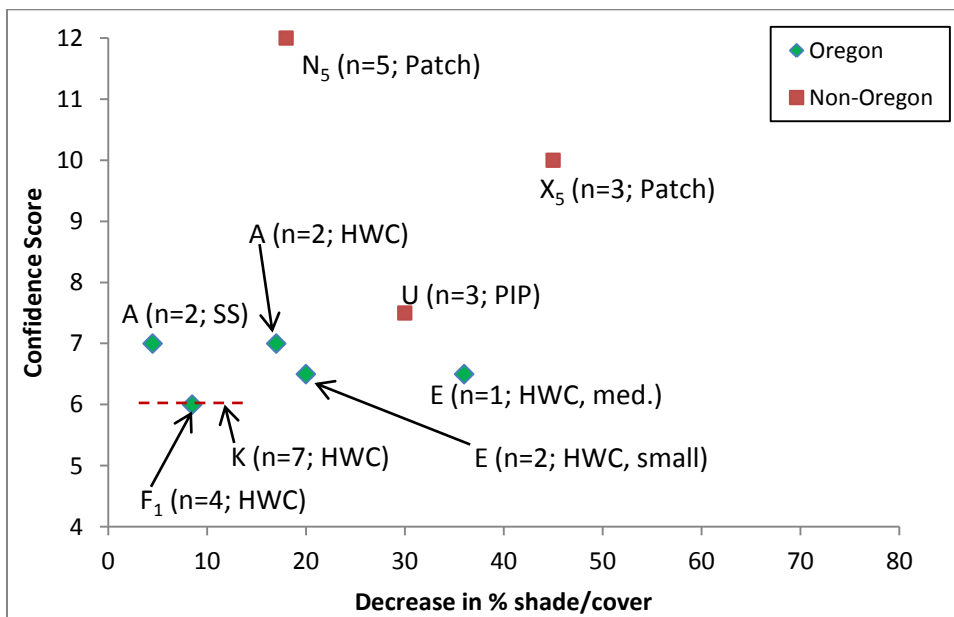
### ***3.6.6 Plan for Alternate Practice***

*Description of rule alternative: This alternative allows site-specific practices and is designed to provide flexibility for landowners. For the purposes of this rule analysis, this alternative encompasses practices not included in any of the other rule alternatives.*

Multiple alternate practices were considered in the reviewed publications. Hardwood conversion (HWC), patch, perennial initiation point, non-merchantable, and site-specific buffers were evaluated in riparian shade studies (three of the seven studies were conducted in Oregon); only hardwood conversion, patch, and non-merchantable buffers were assessed in stream temperature studies (two hardwood conversion studies from Oregon). Hardwood conversion buffers followed state-specified rules for converting hardwood-dominated buffers to conifer (Allen and Dent, 2001; Dent and Walsh, 1997; Dent, 2001; Hunter, 2010). Patch buffers had 164- to 360-foot-long sections of forested buffer with the rest of the catchment clearcut (Janisch

et al., 2012; Wilk et al., 2010). Perennial initiation point buffers had a 56-foot radial buffer emanating from the point of perennial streamflow initiation (Schuett-Hames et al., 2012). Site-specific buffers were not well-defined, but were intended to “enhance and restore riparian areas” (Allen and Dent, 2001).

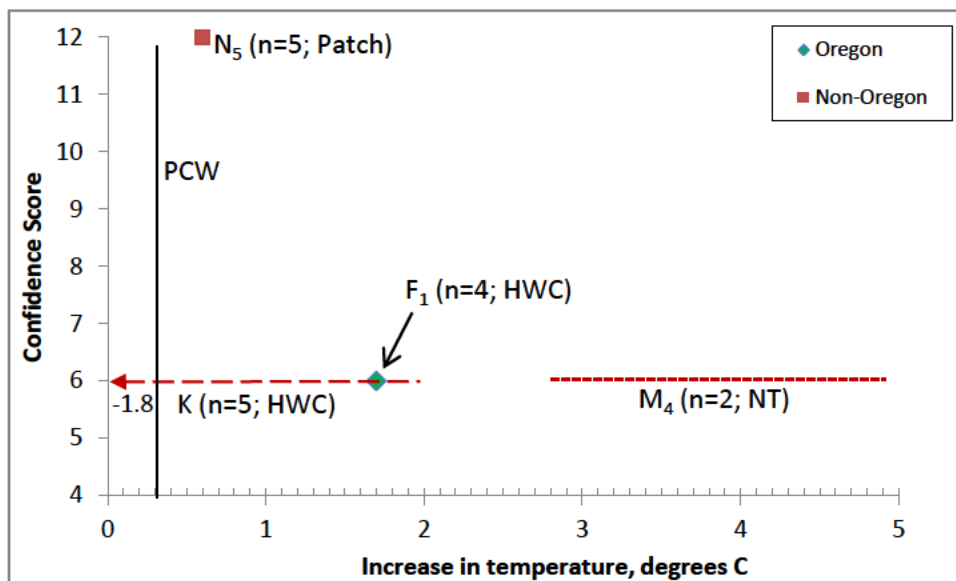
Effectiveness in protecting against decreases in riparian shade varied among the different alternate practices investigated (Figure 12). The most effective was the site-specific buffers, which had an average decrease in canopy density of 4.5%, but confidence in this finding is limited by a low number of sites (n=2). HWC buffers resulted in a 10% to 20% reduction of canopy density for small streams (Allen and Dent, 2001; Dent and Walsh, 1997; Dent, 2001; Hunter, 2012), whereas that of the only medium HWC stream surveyed had a reduction of 36% (Dent, 2001). The patch buffers decreased canopy density by 18%, on average (Janisch et al., 2012; Wilk et al. (2010) reported a 45% reduction in the same study, but using a smaller sample size). The perennial initiation point (Schuett-Hames et al., 2012) and non-merchantable tree buffers (Jackson et al., 2007) were not generally effective, with 30% and 58% reductions in canopy densities, respectively.



**Figure 12. Decrease in shade for sites with alternate practices buffers.**

Letter refers to publication ID (Table 2), n is the number of sites, and capitol letters in parentheses refer to: HWC=hardwood conversion; NT=nonmerchantable tree; PIP=point of initiation of perennial flow; SS=site specific plan; and Patch are buffers left in patches along sensitive reaches. Data from X- and Y-axes are listed in Table 2.

Only one patch buffer measurement location in all of the alternate practices studies appeared to prevent a PCW criterion exceedance: a patch buffer with an increase of 0.1 °C (Figure 13; Janisch et al., 2012), although their average temperature increase was 0.7 °C (n=5). Hardwood conversion buffers resulted in a wide range of temperature responses, spanning from a few sites that appeared to meet the PCW criterion (decrease in temperature of 1.8 °C; Hunter et al., 2012) to increases of more than 3°C (Dent and Walsh, 1997). Non-merchantable buffers were also not generally effective, with measured increases of 2.8 and 4.9 °C (Jackson et al., 2001).



**Figure 13. Increase in temperature for sites with alternate practices buffers.**

Letter refers to publication ID (Table 2), n is the number of sites, PCW is the protecting cold water criterion, and capitol letters in parentheses refer to: HWC=hardwood conversion; NT=nonmerchantable tree; PIP=point of initiation of perennial flow; SS=site specific plan; and Patch are buffers left in patches along sensitive reaches. Dashed lines indicate a range of outcomes for sites for which averaging is inappropriate (e.g., due to different buffer widths). Dashed lines with arrow heads and accompanying number indicate range extended beyond X-axis. Data from X- and Y-axes are listed in Table 2.

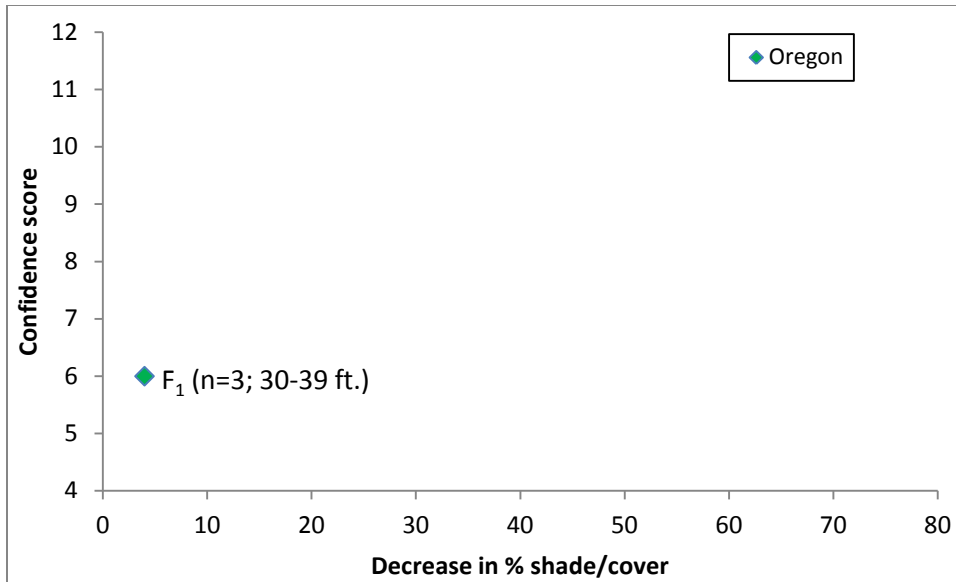
Information on specific alternate practices is too sparse to make a definitive assessment as to the true effectiveness of each. It appears that non-merchantable and perennial initiation point buffers did not meet the PCW criterion. HWC buffers, for which the greatest amount of information exists, along with site-specific and patch buffers, have the potential to protect against PCW exceedance. However, additional study is needed, with particular focus given to controlling for effects modifiers such that the design specifications necessary to provide adequate protection to the stream can be constrained.

### **3.6.7 One-sided Buffer**

Description of rule alternative: *This alternative maintains trees on south sides of streams.*

Two different publications located at the same sites during the same time-frame examined three hardwood conversion units with limited openings on the south side of the stream (Dent and Walsh, 1997; Zwieniecki and Newton, 1999). Buffer widths ranged from 18 to 131 feet, and harvest units were between 1100 feet to nearly one mile in length.

Dent and Walsh (1997) described a 4% (range: 0-7%) decrease in cover at the sites post-harvest (Figure 14), but Zwieniecki and Newton (1999) reported no difference in shade post-harvest, though results were not separated by prescription. Considering the difference in results, the range of variability for shade measures and the low sample size, these results are relatively inconclusive.

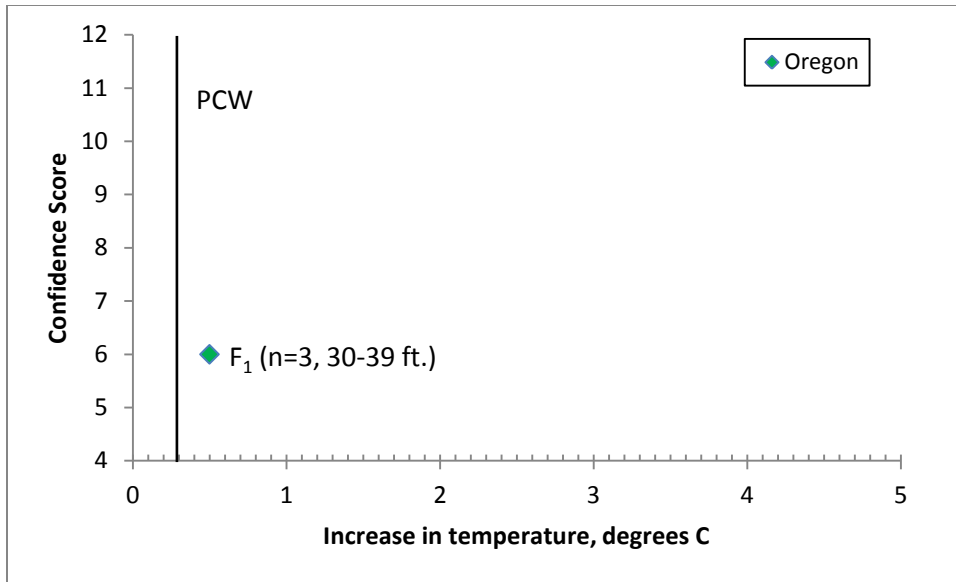


**Figure 14. Decrease in shade for sites with south-sided buffers.**

Letter refers to publication ID (Table 2), n is the number of sites, and distance is the width of buffer. Data from X- and Y-axes are listed in Table 2.

Despite small changes in cover, stream temperatures appeared to increase above the PCW criterion. Both publications showed an increase in stream temperature post-harvest: 0.7 °C (Figure 15; range: +0.07 to +2.6 °C; Dent and Walsh, 1997) and 0.5 °C (Zwieniecki and Newton, 1999; Table 2). Differences in results are likely due to differences in sampling method: both publications collected the 7 day moving mean maximum temperature, but sampling occurred in July and August for Zwieniecki and Newton (1999) and generally between July and early September for Dent and Walsh (1997). Regardless, sample sizes were low and results by individual site are not conclusive of a general trend of increase in temperature (Completed Tables A.6.2). Reanalysis of those data by Newton and Cole (2013b) suggest more confidence that warming occurred post-harvest.

These studies took into consideration stream characteristics, landscape position and stand characteristics such as buffer width and cover. Zwieniecki and Newton (1999) modeled behavior from multiple prescriptions using these effects modifiers; however, the sample size for one-sided buffers is too small to encompass the variability and compare differences between treatments in a statistical test.



**Figure 15. Increase in temperature for sites with south-sided buffers.**

Letter refers to publication ID (Table 2), n is the number of sites, distance is the width of buffers, and PCW is the protecting cold water criterion. Data from X- and Y-axes are listed in Table 2.

### 3.7 Study Limitations and Knowledge Gaps

Although a relatively significant amount of information is available regarding stream temperature and riparian shade responses to forest management, the ability to identify emergent trends across studies is hampered by several factors. The primary limitation is the inconsistencies between study designs and analysis methodologies, particularly the adequate measurement of, and incorporation of, effects modifiers into the assessment. Deciphering observed differences in responses between similar buffer designs is extremely difficult if effects modifiers have not been controlled for in the study design and analysis. The generally low sample sizes (especially within buffer management types) and inconsistency in assessment of effects modifiers made traditional statistical models inappropriate, thereby making comparisons between studies challenging. Another study design-related limitation is that several studies collected a wealth of data but offered very little for inferring their results to other locations because they were essentially designed as a series of single-stream case studies rather than replicated sampling (Rashin et al., 1992; Dent and Walsh, 1997; Martin, 2004; Hunter, 2010).

A somewhat related limitation is the use of a variety of response metrics. This primarily applies to stream temperature studies where the time series of temperature data can be reduced or

averaged in many ways, but it also applies to shade studies where different methodologies for collecting and processing canopy density data generate different metrics, such as canopy density percent, global site factor, and canopy and topographic density. Results are more difficult to compare across studies when the measured response metrics are dissimilar.

A major finding of this SR effort is the lack of studies that were highly relevant to proposed rule alternatives other than the no-cut buffer. Twelve different studies (15 publications) investigated no-cut buffers of various widths compared to only four (7 publications) for the current FPA and only one (3 publications) for the current State Forests standards. Seven studies were highly relevant to the Alternative Practices rule alternative, but within that category the most studies related to any one specific alternative practice was three (hardwood conversion). Nine rule alternatives did not have any highly relevant studies. Studies ranked low relevance with respect to a rule alternative were generally more numerous across the rule alternatives. However, extracting rigorous information that is applicable to a rule alternative, from studies of low relevance to that alternative, is extremely challenging and highly prone to mischaracterization.

Several studies were not focused directly on the review questions of stream temperature or riparian shade response to forest management, and data relevant to this effort were not collected as a primary goal of the original study (e.g., Brosnoff et al., 1997; Danehy et al., 2007; Jackson et al., 2007; Wilk et al., 2010). Though these studies were considered highly relevant to at least one rule alternative, sample sizes were small (Wilk et al., 2010), no pre-treatment data were collected (Brosnoff et al., 1997), and their lack of relevance to the review question perhaps limited confidence in the findings.

#### **4. Lessons Learned – External Scientists’ perspective**

Utilization of the systematic review process is still being tested and several lessons were learned that may help inform future review efforts.

First, the process employed in this systematic review was helpful in initiating conversation between the reviewers. The process included an initial review of four publications that were compared between reviewers. Comparing reviews resulted in conversation about terminology, discussion of how tables should be completed, and a shared understanding of

definitions. It would be useful for the four review papers to provide a spectrum of challenges and test the range of definitions so that reviewers are also better prepared.

As with any new process, methods can be developed but are not reliable until they have been tested. Time and resources on behalf of the reviewers may have been saved if definitions and tables were tested prior to engaging the reviewers. If there is a desire to standardize tables, it might also be useful to provide an example of the type of information to be collected in the table, possibly using an example of one of the papers not chosen for inclusion in the study.

The systematic review question is focused on meeting the information needs of policy-makers; however, few of the studies were conducted specifically to answer the question posed. The uniqueness of the studies made it challenging to compare data and to answer the systematic review question. As described in Study Limitations (Section 3.7), the vast difference in study designs made it challenging to objectively assess the study design and statistical methods. For example, sample sizes were frequently low; data on effects modifiers were often collected, but not always analyzed; if there were pre-treatment data, they were frequently only for one year, which may be adequate for assessing shade, but may not be adequate for assessing temperature.

The systematic review publication search and filter results were heavily balanced towards particular buffer management types (i.e., FPA, derived no-cut); therefore, it might have been advantageous to open up the review to studies outside of the region to provide some insight on those management types that had no studies of high relevancy. However, such an action would have made interpretation more challenging and transference to this region would likely be uncertain. Also, there were studies that fell into the category of “Plan for alternate practice” which cannot be easily compared to each other or any of the other buffer management types; therefore, there is too much variability in study designs to provide a strong basis for management decisions.

Finally, reading and understanding a study well enough to summarize it takes time. Results can be skimmed through and extracted relatively quickly, but to be able to understand the context of those results so that they can be compared to other studies takes more effort in reading and interpretation. For example, a temperature increase of 0.7 °C can be extracted looking at figures and tables, but management practice and effects modifiers need to be considered, as well as data collection and statistical analysis methods. Furthermore, once data have been gleaned

from a paper or report, additional time is needed to assess comparisons between studies, especially when methods are substantially different from each other. We recommend time be allowed for the reviewer to re-familiarize themselves with the papers prior to writing the report, as it will necessarily take some time from the review of the first papers to the time when writing must begin. Mechanisms for reducing this need for additional review should be considered.

## **5. References**

Allen M, Dent L. 2001. Shade conditions over forested streams in the Blue Mountain and Coast Range georegions of Oregon . Oregon Department of Forestry

Beitinger TL, Fitzpatrick LC. 1979. Physiological and ecological correlates of preferred temperature in fish. *American Zoologist* **19** : 319–329.

Bowler D, Hannah D, Orr H, Pullin A. 2008. What are the effects of wooded riparian zones on stream temperatures and stream biota? . CEE Review. Collaboration for Environmental Evidence [online] Available from:  
[http://www.environmentalevidence.org/Documents/Final\\_protocols/Protocol45.pdf](http://www.environmentalevidence.org/Documents/Final_protocols/Protocol45.pdf)

Brazier JR, Brown GW. 1973. Buffer strips for stream temperature control . OSU School of Forestry: Corvallis, OR

Brosofske KD, Chen J, Naiman RJ, Franklin JF. 1997. Harvesting effects on microclimatic gradients from small streams to uplands in western Washington. *Ecological applications* **7** : 1188–1200.

Brown GW. 1969. Predicting temperatures of small streams. *Water Resources Research* **5** : 68–75.

Brown GW, Krygier JT. 1970. Effects of clear-cutting on stream temperature. *Water Resources Research* **6** : 1133–1139.

Burnett KM, Giannico GR, Behan J. 2008. A Pilot Test of Systematic Review Techniques: Evaluating Whether Wood Placements in Streams of the Pacific Northwest Affect Salmonid Abundance, Growth, Survival or Habitat Complexity . Final Report on Findings. Institute for Natural Resources, Oregon State University: Corvallis, OR [online] Available from:  
<http://oregonstate.edu/inr/Burnett-2008> (Accessed 14 November 2012)

Centre for Evidence-based Conservation. 2013. Guidelines for Systematic Reviews in Environmental Management, version 4.2

Danehy RJ, Chan SS, Lester GT, Langshaw RB, Turner TR. 2007. Periphyton and macroinvertebrate assemblage structure in headwaters bordered by mature, thinned, and clearcut Douglas-fir stands. *Forest Science* **53** : 294–307.

Davies-Colley RJ, Payne GW. 1998. Measuring stream shade. *Journal of the North American Benthological Society* **17** : 250–260.

Dent L. 1995. Influence of small clearcut openings in riparian areas on summer stream temperatures on coastal Oregon and western Cascade streams. . COPE Report. Oregon State University College of Forestry

Dent L. 2001. Harvest effects on riparian function and structure under current Oregon Forest Practice Rules

Dent LF, Walsh JBS. 1997. Effectiveness of riparian management areas and hardwood conversions in maintaining stream temperature. *Forest Practices Technical Report* **3**

Fazey I, Salisbury JG. 2002. Evidence-based environmental management: What can medicine and public health tell us? presented at the National Institute for the Environment, Australian National University. Canberra, Australia. 24 June

Gomi T, Moore RD, Dhakal AS. 2006. Headwater stream temperature response to clear-cut harvesting with different riparian treatments, coastal British Columbia, Canada. *Water Resources Research* **42** DOI: W08437 Artn w08437 [online] Available from: [://000240338800001](http://dx.doi.org/10.1029/2005WR004337)

Groom JD, Dent L, Madsen LJ, Fleuret J. 2011a. Response of western Oregon (USA) stream temperatures to contemporary forest management. *Forest Ecology and Management* **262** : 1618–1629.

Groom JD, Dent L, Madsen LJ. 2011b. Stream temperature change detection for state and private forests in the Oregon Coast Range. *Water Resources Research* **47** [online] Available from: <http://www.scopus.com/inward/record.url?eid=2-s2.0-78651287146&partnerID=40&md5=9d7b88edf8674f311f225f94a1e73358>

Groom JD, Johnson SL, Ice GG, Seeds JS. 2013. Timber harvest and the assessment of Oregon's Biologically-Based Numeric Criteria in Coast Range streams (in prep)

Hale VC. 2007. A physical and chemical characterization of stream water draining three Oregon Coast Range catchments

Hunter MA. 2010. Water Temperature Evaluation of Hardwood Conversion Treatment Sites Data Collection Report [online] Available from: [http://www.dnr.wa.gov/Publications/fp\\_cmer\\_05\\_513.pdf](http://www.dnr.wa.gov/Publications/fp_cmer_05_513.pdf) (Accessed 19 February 2013)

Jackson CR, Batzer DP, Cross SS, Haggerty SM, Sturm CA. 2007. Headwater streams and timber harvest: channel, macroinvertebrate, and amphibian response and recovery. *Special issue: Science and management of forest headwater streams* **53** : 356–370.

Jackson CR, Sturm CA, Ward JM. 2001. Timber harvest impacts on small headwater stream channels in the coast ranges of Washington. *Journal of the American Water Resources Association* **37** : 1533–1549.

Janisch JE, Wondzell SM, Ehinger WJ. 2012. Headwater stream temperature: Interpreting response after logging, with and without riparian buffers, Washington, USA. *Forest Ecology and Management* **270** : 302–313.

Johnson SL. 2004. Factors influencing stream temperature in small streams: Substrate effects and a shading experiment. *Canadian Journal of Fisheries and Aquatic Science* **57 (Suppl. 2)** : 30–39.

Johnson SL, Jones JA. 2000. Stream temperature responses to forest harvest and debris flows in western Cascades, Oregon. *Canadian Journal of Fisheries and Aquatic Sciences* **57** : 30–39.

Kiffney PM, Richardson JS, Bull JP. 2003. Responses of periphyton and insects to experimental manipulation of riparian buffer width along forest streams. *Journal of Applied Ecology* **40** : 1060–1076.

Martin DJ. 2004. The Effectiveness of Riparian Buffer Zones for the Protection of Water Quality and Fish Habitat in Michael Creek . Alaska Department of Natural Resources: Juneau, AK

Morman D. 1993. Riparian rule effectiveness study report . Forest Practices Program, Oregon Department of Forestry [online] Available from: <http://www.getcited.org/pub/100206391> (Accessed 19 February 2013)

Newton M, Cole EC. 2013a. Influence of Streamside Buffers on Near-Stream Environment Following Clearcut Harvesting in Western Oregon. in prep

Newton M, Cole EC. 2013b. Stream temperature and streamside cover 14-17 years after clearcutting along small forested streams, western Oregon. *Western Journal of Applied Forestry* **28** : 107–115.

Oregon Department of Environmental Quality (ODEQ). 2004. Final temperature rule and other water quality standards revisions

Oregon Department of Forestry. 1994. FP Technical Note 1: Water Classification

Oregon Department of Forestry. 2010. Forest Practices Administrative Rules

Oregon Department of Forestry (ODF). 2001. Northwest Oregon State Forests Management Plan, Appendix J: Management standards for aquatic and riparian areas . Salem, OR

Rashin E, Washington (State), Watershed Assessments Section. 1992. Effectiveness of Washington's forest practice riparian management zone regulations for protection of stream

temperature / Graber, Craig. . Washington State Dept. of Ecology, Environmental Investigations and Laboratory Services Program, Watershed Assessments Section: Olympia, Wash.

Richter A, Kolmes SA. 2005. Maximum temperature limits for chinook, coho, and chum salmon, and steelhead trout in the Pacific Northwest. *Reviews in Fisheries Science* **13** : 23–49.

Schuett-Hames D, Roorbach A, Conrad R. 2012. Results of the Westside Type N Buffer Characteristics, Integrity and Function Study Final Report [online] Available from: [http://www.dnr.wa.gov/Publications/fp\\_cmer\\_12\\_1201.pdf](http://www.dnr.wa.gov/Publications/fp_cmer_12_1201.pdf) (Accessed 19 February 2013)

Sinokrot BA, Stefan HG. 1993. Stream temperature dynamics: measurements and modeling. *Water Resources Research* **29** : 2299–2312.

Steinblums IJ, Froehlich HA, Lyons JK. 1984. Designing stable buffer strips for stream protection. *Journal of Forestry* **82** : 49–52.

Veldhuisen C, Couvelier D. 2006. Summer Temperatures of Skagit Basin Headwater Streams: Results of 2001 – 2003 Monitoring

Wilk RJ, Raphael MG, Nations CS, Ricklefs JD. 2010. Initial response of small ground-dwelling mammals to forest alternative buffers along headwater streams in the Washington Coast Range, USA. *Forest ecology and management* **260** : 1567–1578.

Zwieniecki MA, Newton M. 1999. Influence of streamside cover and stream features on temperature trends in forested streams of western Oregon. *Western Journal of Applied Forestry* **14** : 106–113.

## **Appendix A. Protocol and Data Table format**

This appendix presents the protocol as approved by the Board of Forestry on 6 March, 2013. Additions to the protocol are indicated by underlined, red font, with deleted text in ~~strike through~~. Reasoning behind substantial changes are clarified in subsection A.7.

*For small and medium streams in the western Pacific Northwest, in or adjacent to forest harvest operations, what are the effects of near-stream forest management on stream temperature and/or riparian shade?*

Systematic Review Protocol

Oregon Department of Forestry, 2600 State St., Bld. D, Salem, OR 97310, USA.

### **A.1 Introduction**

#### ***A.1.1 Background***

Many Oregon streams support several cold-water fisheries (e.g. salmon, steelhead, cutthroat) which are important to the region's economy, culture, and recreational activities. These fish are thermally adapted to specific water temperature regimes for various life stages such as egg and smolt survival, spawning, and adult migration (Richter and Kolmes, 2005). These regimes are affected by several natural processes including direct exposure to sunlight, the transfer of heat from water to the air or stream bed, evaporation, water exchange with groundwater or the hyporheic zone, and others (Brown, 1969; Johnson, 2004). Of these factors, direct exposure to sunlight is a major contributor to maximum daily summer stream temperatures, and this exposure may increase following timber harvest (Brown and Krygier, 1970; Johnson, 2004; Sinokrot and Stefan, 1993). Therefore, maintaining riparian shade may serve as an effective tool for minimizing the increases in stream temperature during the summer months when maximum stream temperatures are observed (Johnson, 2004).

Oregon has enacted timber harvest regulations to maintain shade on streams following timber harvest (Oregon Department of Forestry, 2010). Timber harvest operations are considered in compliance with Oregon Department of Environmental Quality (DEQ) water quality standards (Oregon Department of Environmental Quality (ODEQ), 2004) if harvest operations comply with the Forest Practices Act (FPA; ORS 527.770). The Oregon Department of Forestry (ODF)

must establish best management practices and rules that will meet state water quality standards and periodically conduct studies to determine if the FPA effectively meets state water quality standards (ORS 527.765, 527.710).

ODF initiated its Riparian and Stream Function (RipStream) monitoring project in 2002 to assess the effectiveness of FPA and State Forests standards at complying with DEQ water quality standards for temperature. One of the temperature criteria examined was the Protecting Cold Water (PCW) criterion, which is designed to prevent warming of streams that are currently cold enough to protect fish. This criterion prohibits human activities such as timber harvest from increasing stream temperatures by more than 0.3 °C at the point of maximum impact where: a) salmon, steelhead or bull trout are present; b) streams are designated as critical habitat for salmonids; or c) streams are necessary to provide cold water to a) (OAR 340-041-0028 (11)). An analysis of the pre and post-harvest data indicated that the PCW criterion was likely not being met at all study sites with FPA buffers (i.e., these sites frequently exhibited temperature increases greater than 0.3 °C; (Groom et al., 2011b)). This finding of degradation has initiated an FPA riparian rule analysis process. The geographic scope of the findings of degradation are based on (Groom et al., 2011b), which studied streams in the Coast Range and Interior Geographic Regions of Oregon (as defined in OAR 629-635-0220). While the exact geographic extent of the rule analysis is yet to be determined, it will be limited to western Oregon. This limitation is due to the vegetation, climate and hydrologic characteristics of eastern Oregon being significantly different enough from those included in the RipStream study to preclude extending a rule to eastern Oregon. As part of this rule analysis process, stakeholders contributed 16 alternative methods of riparian management as options for meeting the PCW standard during future near-stream harvest operations. The Oregon Board of Forestry approved consideration of these 16 alternatives at their July 2012 meeting.

ODF is conducting this systematic review (SR) to fulfill a requirement of the rule analysis process: proposed rules must reflect available scientific information (ORS 527.714 (5)(c)). The SR will also serve to inform the decision on the geographic extent of the rule analysis process relative to the RipStream findings on FPA sufficiency. Therefore, this SR will, through evaluating a focused question, directly assist in evaluating the 16 alternative scenarios for riparian management and help inform ODF rule analysis process. However, this review will

not recommend which alternative is the best to choose, nor explicitly define a particular rule prescription.

### ***A.1.2 Protocol for Systematic Review***

Protocols provide a road map for how to conduct a systematic review of scientific literature relevant to a narrowly-defined question (Centre for Evidence-based Conservation, 2013). A systematic review seeks to answer this question with evidence, as opposed to the authors' interpretation of such evidence, from existing studies that are rigorously screened for quality and relevance to this question. The structured process provides for transparency concerning how studies are searched for, which ones are included in the review, and how they are analyzed. This structure also allows for a review to either be updated in the future, or completed by another party. Elements incorporated in a systematic review are outlined in Table A.1.

**Table A.1 Elements described in a protocol for conducting a systematic review.**

<b>Elements</b>	<b>Brief explanation</b>
Question	Focused, scientifically answerable question that guides search strategy and inclusion criteria
Search strategy	Methods (e.g., search terms and databases) to find studies pertinent to question
Inclusion criteria	Filters used to determine relevance of studies to question
Study quality and relevance assessment	Criteria used to determine strength of study methodology, and the relevance of study findings to the review question
Data extraction	Tables used for consistently recording data and meta-data from studies and associated reviewer notes
Data synthesis	Methods (quantitative, qualitative) used for synthesizing data with respect to the review question

### ***A.1.3 Review partners***

Numerous partners are helping to strengthen the quality of this systematic review. We obtained input on both the formulation of the review question and this protocol from a group of stakeholders, the external reviewers, and the RipStream External Review Team (RSERT). These groups included university, federal, forest industry, and state scientists; staff from the Oregon Departments of Forestry, Environmental Quality, and Fish & Wildlife; and nongovernmental organizations including Pacific Rivers Council. Similarly, a reference librarian from the Oregon

State Library assisted in refining the search strategy. Finally, ODF staff composed initial drafts of the protocol and question, and will coordinate the work of these partners and the completion of the final SR report. This protocol might be slightly modified during the review process if external reviewers find ways to improve it. Any changes to this protocol will be coordinated by ODF, and fully documented for transparency. All mentioned partners will have the opportunity to review the completed SR report.

ODF will use external scientists to conduct the review. These reviewers will first cross-check their work by reviewing a subset of studies (including assessing their study relevance, quality, and extracting the data). Each reviewer will then independently review half the remaining studies included in the review. After analyzing the articles, the reviewers will write a report synthesizing their analyses.

## **A.2 Objective of the Review**

This systematic review is designed to provide scientific guidance, per Oregon Revised Statutes 527.714 (5)(c), to the Oregon Board of Forestry in addressing the following rule analysis objective developed by the Board at their April 2012 meeting:

***Establish riparian protection measures for small and medium fish-bearing streams that maintain and promote shade conditions that insure, to the maximum extent practicable, the achievement of the Protecting Cold Water criterion.***

Small streams are defined as having average annual flows  $\leq 57$  L/s (2 cfs), and medium streams are defined as having flows  $> 57$  L/s (2 cfs) and  $\leq 283$  L/s (10 cfs; Oregon Department of Forestry, 2010). Fish-bearing streams are those for which anadromous, game, or threatened and endangered fish presence has been observed or modeled. Specifically, this review is designed to provide insight on the efficacy of the 16 rule alternatives that were approved by the Board at their July 2012 meeting (Table A.5.1). A secondary purpose is to inform the Board's decision on the geographic extent of the rule analysis process.

This review will represent a less-extensive effort than typical systematic reviews. Guidance from the Collaboration for Environmental Evidence (CEBC) suggests extracting primary data from all studies to complete a quantitative analysis (e.g., meta-analysis). We decided against conducting a meta-analysis due to the limited budget, time, and need for such an

extensive analysis. In addition, such an analysis is often not possible in natural resources due to differences in study methods and questions examined (Centre for Evidence-based Conservation, 2013). CEBC guidance suggests exploring all possible sources of data (including e.g., on-going or never-published studies) and contacting study authors to obtain primary data. As noted below, our search strategy and types of studies included in the review are well-defined, although they are not as extensive as suggested in the guidance. We decided to include studies that pass a certain level of rigor (i.e., peer-reviewed literature, manuscripts in review, and graduate theses), and governmental studies, the latter of which are likely the most relevant to the review questions. These decisions are expected to provide an adequate level of information while speeding up the review process and limiting expenditures; typical systematic reviews cost approximately \$100,000 and take a year to complete (Collaboration for Environmental Evidence, personal communication, Oct. 2012).

#### ***A.2.1 Primary review question***

Systematic reviews are designed to assess a body of literature through the lens of a focused question regarding the efficacy of active treatments, rather than a general topic of concern to policy or practice. The question should be value-free to the extent possible, answerable in scientific terms, and specify the subject, treatment, comparator, and outcome(s) of interest. The question is also important since it is used to generate terms used in the literature search and to determine relevance criteria.

The review question was developed by several partners in stages. ODF staff (T. Frueh, J. Groom, and M. Allen) developed a draft review question. The question was refined in consultation with the external reviewers, representative stakeholders, and RSERT to ensure the question's importance and appropriateness of scope for this review. The question was then further refined with ODF input. The review question is:

***For small and medium streams in the western Pacific Northwest, in or adjacent to forest harvest operations, what are the effects of near-stream forest management on stream temperature and/or riparian shade?***

The elements of the question are based on the rule objective (see above) and the finding of degradation. The question is limited to western Pacific Northwest (e.g., wet, temperate

climates) since these areas might have similar-enough characteristics (i.e., vegetation, hydrology, climate) to provide insight on the effects of riparian buffers on stream temperature or riparian shade in western Oregon. The purpose of the rule objective is to protect stream temperature within the context of harvesting forests, thus the examination of the effects of near-stream forest management in the context of forest harvest operations.

**Table A.2.2 Definition of components of the primary systematic review question.**

Population	Small and medium streams in forest harvest operations in western PNW forests
Intervention	Riparian management areas (e.g., buffers) for protecting cold water or riparian shade
Comparator	Lack of forest harvest
Outcomes	Change in stream temperature or riparian shade

### ***A.2.2 Secondary question***

This review will evaluate differences between studies that might explain variations among study outcomes. These differences may be due to effects modifiers (see Section A.3.3 for more information on these modifiers), and this secondary question explicitly addresses the causes of these differences. To the extent that relevant information is available in reviewed studies, this secondary question will be addressed:

***For small and medium streams in the western Pacific Northwest, in or adjacent to forest harvest operations, how do effects modifiers (e.g., discharge, substrate characteristics, length of buffers, stream aspect), in combination with near-stream forest management, change stream temperatures or riparian shade?***

## **A.3 Methods**

### ***A.3.1 Search strategy***

An important aspect of systematic review is the use of a search strategy that specifies, *a priori*, how a comprehensive and unbiased sample of the literature will be searched. For this review, the search strategy was drafted by ODF staff and modified following input from external reviewers, RSERT, and Stakeholders. In addition, a reference librarian from the Oregon State Library guided its refinement using professional judgment and test searches. We decided to search as wide as possible, then use rigorous inclusion criteria to determine which studies to

include. All publications found in each searched source will be imported into bibliographical management software, except for internet searches from which the first 100 results will be reviewed for relevant publications. Results with indeterminate information (e.g., incomplete citation) or that are duplicates will be discarded. The source of each reviewed publication will be specified in the study inclusion table (Table A.6.1).

Search terms are divided into sets that represent an element of the review question. Terms within each set will be combined via Boolean operators (e.g., AND, OR) with those of each term within the other sets. These terms were determined via consultation with ODF partners, and by looking at a protocol of a similar SR (Bowler et al., 2008). Search terms (\* indicates wildcard search term):

**Set 1. Management activity**

(\*Forest\* or wood\* or tree\*) AND (thin\* or harvest\* or clear\* or cut\* or remov\* or regenerat\*)

**Set 2. Treatment/intervention**

(Riparian or streamside or “stream-adjacent” or “near stream”) AND (buffer\* or reserve\* or manage\* or zone\* or leave\* or veg\* or strip \* or area or canopy or wood\*)

**Set. 3 Outcome**

(“stream temperature” or “water temperature” or shade or cover)

For every search, the following information will be documented:

- Date when search was conducted
- Database, search engines, websites, or professional network that was searched
- Exact search strings used

The following electronic resources will be searched:

- Scopus
- World Cat
- CAB Abstracts
- Tree Search: USDA Forest Service Research
- AGRICOLA: Ebsco

- Streamnet Library Columbia Basin
- WAVES Canada: Libraries of Fisheries and Oceans Canada

An Internet search will be performed using the following search engines:

- www.yahoo.com;
- www.bing.com;
- google.com;
- www.scholar.google.com; and
- www.dogpile.com.

The first 100 hits from each internet search will be examined for appropriate studies.

Because disciplines related to stream temperature use diverse study designs and have little consensus on key terms, the systematic search will be augmented with an *ad hoc* search to avoid omitting useful publications. In the ad hoc search, bibliographies and citation searches of included studies and any traditional reviews will be examined for relevant references.

Additionally, email or phone queries concerning obscure studies will be sent to scientists and stakeholders (e.g., participating environmental NGOs) in the Pacific Northwest who study, or work with people who study, riparian buffers, stream temperature, or shading of streams.

Searches will also be carried out within the web pages of relevant associations and organizations including, but not limited to:

- the US Environmental Protection Agency;
- National Council for Air and Stream Improvement;
- Washington Dept. of Natural Resources/Cooperative Monitoring, Evaluation and Research Committee;
- Washington Dept. of Ecology/ Forest Practice Effectiveness Monitoring Program;
- California Dept. of Forestry and Fire Protection;
- British Columbia Ministry of Forests, Lands, and Natural Resource Operations;
- US Forest Service;
- Northwest Indian Fisheries Commission;
- Columbia River Inter-Tribal Fisheries Commission;
- Skagit River System Cooperative;
- Canadian Forest Service, Natural Resources Canada;
- Alaska Dept. of Natural Resources/Division of Forestry.

Finally, to capture theses and dissertations that are archived more recently (i.e., not located in regular library catalogs), the search will include catalogues of electronic graduate theses from research universities in the Pacific Northwest:

- Oregon State University;
- University of Oregon;
- Portland State University;
- University of California system;
- University of Alaska;
- University of Washington;
- Washington State University;
- University of British Columbia.

### ***A.3.2 Study inclusion criteria***

Study inclusion criteria are predefined to ensure an objective selection of the relevant literature. For this review, the studies must directly inform the primary review question in the context of the rule alternatives and rule objective. Only primary studies (i.e. studies with original data, not reviews or meta-analyses) will be included since we want to base the rule analysis on evidence, not authors' interpretation of the evidence. While peer-reviewed articles are the gold standard in science, we decided to include "gray literature" (i.e., articles that might have less rigor in either peer-review or research methods and analysis, e.g., government reports, graduate theses) and manuscripts in review because some of these studies are most relevant to the review question. It is a common requirement that agencies (e.g., ODF, Washington Dept. of Natural Resources) assess the effectiveness of their respective rules via studies, thus this gray literature is likely to be highly relevant to the primary review question. In addition, only studies that measure the effects of recent forest harvests, with near-stream areas managed for protecting water (i.e., similar to OAR 629-635-0100), on stream temperature or riparian shade will be included since these elements are essential to analyze the riparian rule objective that provides the impetus for conducting this study. Restricting studies to those of "recent" harvest is warranted due to the decline, with time, of adverse impacts of harvest on stream temperature and riparian shade (Hale, 2007; Johnson and Jones, 2000). The final inclusion criteria are:

- Studies must have proper controls with which to measure the effects of buffer treatments;
- Studies must have been conducted in sites with similar stream sizes and forest types (OAR 629-635- 0310); and
- Studies must have been located in similar forests as that of western Oregon.

Inclusion criteria are further detailed in Table A.6.1.

With these criteria in mind, inclusion will be determined initially on viewing the titles of articles. When titles provide insufficient information to ascertain consistency with inclusion

criteria, the ODF review coordinator will read abstracts to determine inclusion. Where there is still insufficient information to make a decision, an article's inclusion will be determined by reading the full text. Studies that meet all inclusion criteria will be reviewed by the external reviewers. For transparency, the fate (i.e., inclusion or exclusion), and basis for this decision, of each publication found in the search will be documented in Table A.6.1. If a thesis that meets all inclusion criteria and also has a peer-reviewed publication associated with it, only the peer-reviewed publication will be used in the review. For studies from which multiple publications are produced, all publications will be included in the review.

### ***A.3.3 Potential effect modifiers***

While studies may have very similar methods, they may show differences in the measured outcomes. These differences may be due to circumstances ("effects modifiers") that alter the outcomes. For example, two studies may have identical buffer widths, yet if they have different buffer lengths, they might exhibit different changes in stream temperatures. Thus, these effects modifiers are important to consider when synthesizing the extracted data. The role effects modifiers played in study outcomes will be assessed in Table A.6.2 and discussed in the narrative synthesis (Section A.3.6).

The following lists of effects modifiers were determined by: 1) modifying a list of effects modifiers in a systematic review similar to this review (Bowler et al., 2008); 2) examining a subset of studies to see what are considered important effects modifiers; and, 3) incorporating input from RSERT and other technical experts.

#### Factors of, or affecting, the riparian zone:

- Length, width of the riparian reserve
- Tree harvest in part or all of the riparian reserve
- Type of trees e.g. deciduous or non-deciduous
- Tree height, age, distance from edge
- crown height
- Tree density
- Residual stand composition
- Tree/basal area retention amount
- Other riparian vegetation: presence,% cover
- Aspect

- Method of vegetation or tree removal
- Clearcut vs. thin (outside of riparian reserve)
- Harvest on both sides or single side of riparian reserve
- Logs or slash left in stream
- Harvest on both sides or only one side of riparian reserve
- Time since harvest
- Windthrow

Factors of the stream:

- Stream width/depth
- Discharge
- Distance from stream/river source
- Groundwater-surface water interactions
- Connectivity to other streams
- Hyporheic flow
- Flow through, or from, a wetland or lake
- Continuity of flow (seasonally and longitudinally)
- Substrate
- Gradient
- Aspect
- Geology and soils

Additional factors affecting temperature or shade measurements:

- Time of year and season
- Latitude
- Elevation
- Precipitation: volume, rain vs. snow domination
- Potential for topographic shading
- Air temperature
- Cloudiness
- Accuracy and precision of instruments for, and frequency of, data acquisition

***A.3.4 Data extraction strategy***

When conducting a systematic review, it is important to extract both information about studies and their respective primary data. This information focuses the review on evidence instead of authors' interpretation of the evidence. The data extraction tables allow for objective and transparent extraction of this data. In addition, these tables will likely highlight gaps in our understanding. For this study, these data will be compiled in Table A.6.2 for each study. This table was developed by modifying those of (Bowler et al., 2008; Burnett et al., 2008), testing

with several studies, and with input from RSERT and stakeholders. Reviewers will also assess various components (e.g., bias, effects modifiers) that provide a more complete understanding of the context, relevance and relative strength of studies (Table A.6.2).

#### ***A.3.5 Study quality assessment and relevance***

When synthesizing data from the studies, it is important to consider both the quality of each study and its relevance to the review question. For example, a study might have directly addressed the review question, yet was poorly conducted so as to provide little confidence in the study's results. Conversely, a study may have been conducted very well, yet has only weak relevance to the review question.

External reviewers will complete tables that enable quick, objective comparisons of studies. Table A.6.3 addresses the quality of studies by determining e.g., the rigor of their controls, and number of replicates. This table also determines study relevance by determining how close studies are geographically and in stream size to those of (Groom et al., 2011a). Table A.6.4 determines whether studies directly or indirectly addressed a rule alternative, ~~and a relative assessment of the effectiveness of buffer treatments at protecting cold water or shade~~. Additional reviewer notes that further illuminate study quality and reference (e.g., robustness of study measures, sources of bias, consideration of effects modifiers) are listed in Table A.6.2.

#### ***A.3.6 Data synthesis***

To make sense of the information extracted and analyzed from the studies, a narrative synthesis will be composed. This synthesis will assess the differences and commonalities between riparian management scenarios used in studies and their respective outcomes. For each rule alternative, the synthesis will discuss:

- Number of studies that directly or indirectly address the alternative<sup>4</sup>;
- The evidence from a suite of studies regarding the effectiveness of the alternative, including:

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<sup>4</sup> Note that although several publications may be from a single study, this is clarified in the discussion of how many studies addressed an alternative. In addition, a single study may have several publications, each of which addresses a different alternative.

- range of variation in metrics defining each alternative (e.g., buffer width, basal area retention)
- range of variation in outcomes measured
- degree of effectiveness at protecting cold water or riparian shade
- The role of effects modifiers in the stream temperature and riparian shade outcomes that were measured; and
- Significant gaps in our understanding.

The synthesis will also consider the magnitude of influence the effects modifiers had on results, for the full suite of studies. However, the synthesis will not recommend which rule alternative to adopt in the rule analysis process, nor explicitly define a particular rule prescription.

## **A.5 Rule alternatives**

**Table A.5.1 Recommended initial range of alternatives for riparian rule analysis on small and medium fish bearing streams.**

Alternatives were generated from stakeholder and staff input. Proposed alternatives may be either regulatory or voluntary, except for the Oregon Plan (voluntary) and Plan for Alternate Practice (regulatory) alternatives. From [http://www.oregon.gov/odf/Pages/board/BOF\\_072612\\_Meeting.aspx](http://www.oregon.gov/odf/Pages/board/BOF_072612_Meeting.aspx)

Category	Alternative	Scientific Principle(s)
Variable retention buffer	<b>Current FPA:</b> Maintain current standard target prescriptions (no action)	Include no-action as comparison
	<b>State Forests Standards:</b> State Forest Management Plan riparian protection standards. Three (3) zone RMAs with varying retention standards established for multiple purposes including but not limited to maintaining shade.	Shade known key driver of stream temperature increases.
	<b>Derived variable retention:</b> Use collected data or literature to explore a variety of stand metrics versus shade outcomes (including but not limited to RipStream data).	Utilize RipStream and any other relevant monitoring or research data that links riparian stand conditions to shade.
	<b>Large tree variable retention</b> – Emphasizes retention of largest trees close to the stream in addition to a no-cut and variable retention buffer.	Increased riparian basal area linked to higher shade levels.
	<b>Minimize gaps:</b> Maintain existing standard targets but modify current spatial retention standards (basal area/1000 ft) to minimize shade gaps	Strategic RMA tree retention to minimize shade gaps.
	<b>Basal-area retention by aspect:</b> Increase basal area density retention targets on south-sided RMAs only	Aspect known to influence stream temperature and shade.
Shade standard	<b>Field-based shade standard:</b> Establish process to implement field-measured shade standard rather than managing for RMA stand metrics	Shade known key driver of stream temperature increases.
	<b>Shade approach from Washington DNR method:</b> Three (3) zone RMAs based on a combination of site index, shade and basal area retention standards with linkages to applicable temperature standards. Uses channel migration zones (CMZs) versus high water	Shade known key driver of stream temperature increases.

Category	Alternative	Scientific Principle(s)
	level in current Oregon FPA.	
	<b>Shrub shade:</b> Develop alternative to account for shade contribution from shrubs or other non-woody plants.	Sites with significant shrubs or other non-woody plants may allow greater tree removal while maintaining shade.
Hardwood contribution	<b>Hardwood sites:</b> Consider alternatives to account for conifer vs. hardwood-dominated riparian stands.	Hardwoods provide shade but conifer retention emphasis in FPA, does not account for sites poorly suited for conifers.
	<b>Hardwood shade:</b> Include hardwoods in basal area standard target.	Hardwoods provide shade but few count towards current retention targets in FPA.
No-entry buffer	<b>Derived no-cut buffer:</b> No-cut buffer as based on actual shade, temperature, buffer width data or literature (including but not limited to RipStream).	Increased riparian basal area and greater no-entry buffer widths linked to higher shade levels.
	<b>No-cut aspect buffers:</b> No-cut buffers on south-sided RMAs plus standard retention prescription everywhere else.	Aspect and buffer width have been linked to shade levels.
Other	<b>Oregon Plan:</b> Modify Oregon Plan voluntary measures to encourage location of wildlife leave trees within RMAs, both small & medium streams (voluntary alternative).	Increased riparian basal area linked to higher shade levels.
	<b>Plan for alternate practice</b> - Develop criteria to allow for site-specific RMA prescriptions and maintain flexibility while achieving rule objective (regulatory alternative).	Promotion and maintenance of shade can be achieved through a variety of approaches.
One-sided buffer	<b>(added during BOF meeting 7/26/12):</b> Riparian vegetation retained only along the southern portion of a stream	Aspect and buffer width have been linked to shade levels.

## A.6 Data extraction and summary tables

**Table A.6.1 Determination of inclusion of studies, found in the search for potentially relevant literature, in this review.**

“Y” indicates a study meets that inclusion criteria, “N” indicates it does not meet that inclusion criteria. To be excluded from this systematic review, a study must not meet at least one inclusion criteria (note: in order to prevent spending time reading an entire article, searching for exclusion criteria within an article will stop after finding one, and thus a study might meet more of the inclusion criteria than are listed in this table). To be included in this review, a study must meet all of the inclusion criteria. Note: if an insufficient number of studies are found during the search process, this strict exclusion threshold may be re-examined.

Study	Inclusion criteria					
	Outcome <sup>1</sup>	Setting <sup>2</sup>	Intervention <sup>3</sup>	Study design <sup>4</sup>	Study type <sup>5</sup>	Geographic extent <sup>6</sup>

<sup>1</sup> Measured Reported (via at least one figure or table) primary measurements of stream temperature or, riparian shade (or a proxy thereof), or insolation.

<sup>2</sup> Small and medium streams (i.e., with contributing areas or average annual flow less than 1.5 times the upper limit of medium stream defined in (ODF, 1994) ( 11250 ac.(45 km<sup>2</sup>) and 15 cfs, respectively), or wetted width or bankfull width less than 1.1 times the maximum wetted width or bankfull width from (Groom et al., 2011a) (4.0 m and 8.7 m, respectively) in mountainous terrain with forests harvested less than five years before data collection of a study.

<sup>3</sup> Near-stream area managed for protection of cold water and/or riparian shade. Management prescription is clearly quantified (e.g., buffer width, basal area retention).

<sup>4</sup> Controls exist (either pre-treatment data, control sites, or reference sites)

<sup>5</sup> Peer-reviewed papers, government reports, manuscripts in review, and graduate theses, all of which must be primary studies that describe methods and contain primary data.

<sup>6</sup> A portion of the study must have been conducted in any of the following locations: parts of Oregon, Washington, and British Columbia west of the crest of the Cascades, the Siskiyous of northern California, northwest British Columbia, southeast Alaska, or the coastal range of northern California.

**Table A.6.2 Data to be extracted from each publication included in evaluating the review question “For small and medium streams in the western Pacific Northwest, in or adjacent to forest harvest operations, what are the effects of near-stream forest management on stream temperature and/or riparian shade?”**

Studies labeled with a. and b. will be evaluated by both reviewers in order to assess consistency of their respective work. All publications will be identified in the systematic search process except those for which the citation will be followed by a reference to its source in brackets.

Publication title and principal investigator(s)	
Study dates and study duration (# of years, dates within a year)	
Study location (watersheds, region/state, country), settings where riparian buffers were applied	
Ecosystem type; plant association group; type of forest	
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	
Research question(s), hypotheses, objectives	
Study design <sup>1</sup>	
Pretreatment data (yes/no), # of years of pretreatment data	
Details on management action(s) (e.g., <del>examples:</del> sizes and types of buffers; <u>clearcut or thin on both or single sides of streams</u> )	
Replications (if applicable)	
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	
Sample sizes and results <u>with estimates of variation</u> <sup>3</sup>	
<del>Location of results within article (e.g., specific tables &amp; figures, text)</del>	
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	
Potential sources of bias or error	
Effects modifiers <sup>5</sup>	
Notes <sup>6</sup>	
Method references <sup>7</sup>	

<sup>1</sup> ~~Replicated sampling, replicated controls, sampling before and after treatment; unreplicated, controlled, sampling before and after treatment; unreplicated, uncontrolled, sampling before and~~

~~after treatment; unreplicated, controlled, sampling after treatment~~ Brief description of study design, e.g., BACI, # of sites, types of controls (pre-treatment, reference, upstream), site layout.

<sup>2</sup> Examples of outcome measures: stream temperature, basal area, riparian shade; relative importance refers to instances where a proxy is used (e.g., canopy cover for shade at stream surface), how representative is the proxy? Robustness refers to how well outcomes were measured (e.g., accuracy of measurements, frequency, sound method for measuring)

<sup>3</sup> For sample size, list with respect to particular results (e.g., “increase of X degrees (n=4)”); list specific results that are most pertinent to answering the question and help inform the rule analysis objective, referencing a figure or table where appropriate; include confidence limits, ranges, or standard deviations.

<sup>4</sup> Address study quality questions such as: Did authors adequately address fundamental processes? How well did they conduct their statistical analyses? Were biases addressed?

<sup>5</sup> Discuss how well, and which, effects modifiers were considered (see list of effects modifiers in Section A.3.3)

<sup>6</sup> Notes allows for additional insight reviewer may provide on study quality

<sup>7</sup> refers to references that are essential to understanding methods of an article.

**Table A.6.3 Summary of information from each study that indicates its quality and relevance to the review question.**

Study	Quality						Confidence Score*	Relevance			
	Duration <sup>†</sup> Sampling periods	Pre-treatment <sup>1</sup> (yrs)	Study design <sup>2</sup>	N replicate <sup>3</sup>	N control <sup>4</sup>	N samples/sites <sup>5</sup>		Geography <sup>7</sup>	Mountains <sup>8</sup>	Stream size <sup>9</sup>	Question/Objective <sup>10</sup>

<sup>†</sup> ~~The number of sampling seasons for which data were collected.~~ The number of time periods in which data were collected; a time period combines spring, summer, and fall if in same calendar year, and may be as short as one event (e.g., for shade measurements).

<sup>1</sup>Data collected before treatment with the number of years of pre-treatment data in parentheses (X=yes, blank=no)

<sup>2</sup>H=high=Replicated sampling, replicated controls, sampling before and after treatment; M=medium=unreplicated, controlled, sampling before and after treatment; L=low=unreplicated, uncontrolled, sampling before and after treatment or unreplicated, controlled, sampling after treatment (modified from (Fazey and Salisbury, 2002)). If mixture (e.g., some sites with and some sites without replicates), give mixed rating (e.g., L/M).

<sup>3</sup>~~Number of treatment replicates~~ N<sub>replicates</sub> refers the numbers of treatments with the same prescription (e.g., buffer width).

<sup>4</sup>Number of control replicates; add succinct description (e.g., “3 yrs. Post-treatment, treatment X”), knowing that greater detail is captured in Completed A.6.2.

<sup>5</sup>Number of samples (i.e., total number of sites; add succinct description (e.g., “3 yrs. Post-treatment, treatment X”), knowing that greater detail is captured in Completed Table A.6.2.

<sup>6</sup> ~~H=high= stream temperature autocorrelation dealt with, data not combined across sites without accounting for site differences; M=moderate= contains some features of High as applicable; L=low=statistical tests used (or not) but ignore site differences or autocorrelation~~ This category considers two questions: 1) Were the statistical analyses conducted appropriate for the data collected? And, 2) Did study authors adequately explore data (via analyses) to address study questions and objectives? H=high= yes to both questions; M=medium= yes to one question; L=low= no to both questions. Note that this category does not consider study design.

\* Sum of quality points for sampling periods, study design, number of replicates, and statistically robust columns. Points are: H=3, M=2, L=1. for sampling periods; 1, 2, and 3 for 1, 2, and ≥3 seasons, respectively; for number of replicates: 1, 2, 3 for 0, 2-3, and ≥4 replicates, respectively. If a rating is between two categories, then the points are between these two (e.g., L/M, or duration=1 or 2 years, then the points would be 1.5). <sup>7</sup>H=high= west of crest of Cascades in OR,

WA, BC plus the Siskiyous (i.e., sites most similar to those in western Oregon); L=low=Coast Range of N. CA, Vancouver Island, NW BC, SE Alaska (i.e., sites somewhat similar to those in western Oregon).

<sup>8</sup>In mountainous terrain (X=yes, blank=no)

<sup>9</sup>H=high=small or medium streams as defined in either of (Groom et al., 2011b; ODF, 1994) (i.e., with contributing areas ~~less than~~  $\leq 7500$  ac.(30 km<sup>2</sup>), or average annual flow ~~less than~~  $\leq 10$  cfs, or wetted width  $< 3.7$  m ~~wetted width~~, or bankfull width  $< 7.9$  m ~~bankfull width~~); L= low = “near” medium size stream (i.e., contributing areas 7500 - 11250 ac. (30-45 km<sup>2</sup>), or 10 - 15 cfs average annual flow, or 3.7 - 4.0 m wetted width, or 7.9 - 8.7 m bankfull width).

<sup>10</sup>H=high=study objectives or questions directly relate to review question; L=low= study has relevant data even though study objectives or questions are not directly related to review question.

**Table A.6.4 Relevance of each study to each rule alternative as listed in Table A.5.1.**

In relevance row, high relevance (H) indicates study directly addressed a particular rule alternative; low relevance (L) indicates study indirectly addressed a rule alternative; blank indicates did not address rule alternative. The effectiveness row gives a relative rating of how well a particular treatment prevented warming, or decrease in shading, of streams.

Study		Current FPA <sup>1</sup>	State Forests Standards <sup>1</sup>	Derived variable retention	Large tree variable retention	Minimize gaps	Basal area retention by aspect	Field-based shade standard <sup>2</sup>	Shade approach from W/A DNR method	Shrub shade	Hardwood sites	Hardwood shade	Derived no-cut buffer	No-cut aspect buffers	Oregon Plan	Plan for alternative practice <sup>3</sup>	One-sided buffer
	Relevance <sup>4</sup>																
	Effectiveness <sup>5</sup>																
<b>Total # studies (pubs.) High relevance<sup>5</sup></b>																	

<sup>1</sup> Standards are summarized in .

<sup>2</sup> This alternative involves measuring shade at a site, estimating how much shade would be left with removing certain trees, removing these trees, and re-measuring the resultant shade.

<sup>3</sup> Any other type of treatment that may have been studied.

<sup>4</sup> A study is considered directly relevant (H) if it provides quantitative data that addresses whether or not a particular design or prescription of a rule alternative is effective at preventing warming or maintaining shade. A study is considered indirectly relevant (L) if it provides information that can give some insight to effectiveness of a particular rule alternative.

<sup>5</sup> ~~Effective at preventing stream from warming or maintaining shade: ++= prevented warming; += reduced warming; =resulted in maximal warming.~~

<sup>5</sup> Sum of all studies that are highly relevant for each rule alternative; parentheses indicates the total number of publications relevant for a particular alternative if different than the number of studies. See Table 2 for clarification of relationship between studies and publications.

## A.7 Discussion of significant modifications to the protocol

The protocol was modified during the review process, and the majority of these changes were added for clarification. This section discusses changes to the protocol that were more than clarifications.

Section A.3.2 Study inclusion criteria: We decided to include peer-reviewed publications rather than the theses from which they were produced since the former tend to be stronger analyses presented in a more succinct manner. We also decided to include all publications from a study because they typically present different analyses and/or data (e.g., shade vs. temperature, looking at the data differently).

Table A.6.2: Footnote describing “study design” was modified to include more information. The previous method is addressed in the study design category of Table A.6.3.

Table A.6.3:

- The original footnote describing “statistically robust” considered studies that took regular (e.g., hourly) measurements of stream temperature, but did not consider shade or less-regular temperature measurements. The modified footnote addresses studies of any kind, given their particular study design.
- The “confidence score” category was added to give a relative scoring of the quality of each publication reviewed. The scoring method is developed based on objective criteria within this table, and minimizing using elements that confound one-another (e.g., part of the rating for study design incorporates whether or not there was pre-treatment data, thus the pre-treatment column is not included in the confidence score). Adding this score is important to help policy-makers judge the quality of information from a publication, as well as for graphing purposes.
- The “question/objective” category was added to clarify whether or not relevant evidence from a study was in the context of a study that is closely aligned with this review’s primary question.

Table A.6.4:

- “Field-based shade standard” was clarified because it is easy to consider a study that measures shade before and after harvest as being highly relevant. However, the standard is meant to measure shade before, estimate what it will be by harvesting specific trees determined by shade measurements, then re-measuring shade.
- The Effectiveness row was eliminated after doing the evaluations and realizing there was no good, objective way to assess this; instead, summaries (e.g., mean, range) of

effectiveness data (e.g., increase in temperature, decrease in shade/cover) are pulled directly from a publication and entered in Table A.6.2 in the Sample sizes and results row.

## Appendix B. Completed data extraction and study comparison tables

This appendix contains Tables A.6.2-4 completed by the reviewers. The completed version of Table A.6.1 is in Data Supplement 2, Lit\_Search\_Filter. xls.

**Completed Tables A.6.2 Data to be extracted from each publication included in evaluating the review question “For small and medium streams in the western Pacific Northwest, in or adjacent to forest harvest operations, what are the effects of near-stream forest management on stream temperature and/or riparian shade?”**

Studies labeled with A. and B. will be evaluated by both reviewers in order to assess consistency of their respective work. All publications will be identified in the systematic search process except those for which the citation will be followed by a reference to its source in brackets. Note: footnotes are listed only following the first copy of this table.

<b>Publication</b>	A. (Allen and Dent, 2001)
Study dates and study duration (# of years, dates within a year)	Post 1998 but before 2001, not sure of exact dates
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Siletz, Tillamook, Nehalem, Lower Columbia, Necanicum, Clatskanie, and Alsea basins
Ecosystem type; plant association group; type of forest	Riparian areas are typically dominated by an alder overstory and a salmonberry/sword fern understory. Riparian conifer species typically include western hemlock, western red cedar, and/or Sitka spruce. Douglas-fir is more prevalent farther away from the stream. Soils are deep and well-drained.  Average of 90 year old unharvested stands and 65 year old harvested stands (32-120 years and 35-125 years, respectively)
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	Large (6), medium (10), and small (14) type F (fish-bearing) streams, and small type D (domestic water supply) streams Average of 16 ft bankfull width (5-37 ft)

<b>Publication</b>	A. (Allen and Dent, 2001)
Research question(s), hypotheses, objectives	<p>“OBJECTIVES</p> <ol style="list-style-type: none"> <li>1. Document the ranges of shade conditions that occur under a variety of riparian stand structures and disturbance regimes in northeast and northwest Oregon.</li> <li>2. Document the relationships between shade and riparian stand structure, geomorphology, forest management, and other disturbances.</li> </ol> <p>QUESTIONS</p> <ol style="list-style-type: none"> <li>1. What are the ranges in shade conditions over Blue Mountain and Coast Range forested streams and how do they compare between harvested and unharvested stands?</li> <li>2. Do particular Riparian Management Area prescriptions in harvested stands result in different average shade conditions?</li> <li>3. What are the relationships among shade and channel and valley morphology?</li> <li>4. How do disturbances, other than harvesting, affect shade on forested streams?</li> <li>5. What are the relationships between riparian stand characteristics and shade?”</li> </ol>
Study design <sup>1</sup>	<p>30 sites, 21 harvested and 9 unharvested; 22 of 30 were large industrial ownership</p> <p>Plot was established on both sides of the stream, 500-1000 ft. along stream, at least 100 ft from the end of the harvest unit, 100 ft wide on each side of stream (measured from average annual high water)</p> <p>All trees &gt;6 inches DBH measured</p>
Pretreatment data (yes/no), # of years of pretreatment data	No; used set of unharvested reference stands for comparison
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<ul style="list-style-type: none"> <li>• Operations conducted after January 1, 1998.</li> <li>• Harvest units with the same "prescription" on both sides of a stream.</li> <li>• 16 RMAs were managed with a no-cut buffer, 2 riparian conifer restoration, and 3 site-specific plan</li> <li>• All of the adjacent uplands in the Coast Range were clearcut to the buffer's edge (21 out of 21 sites)</li> <li>• Basal area retained on these study sites was in excess of what can result from a basal area</li> </ul>

<b>Publication</b>	A. (Allen and Dent, 2001)
	<p>prescription on small streams</p> <ul style="list-style-type: none"> <li>• Stands with excessive blowdown (&gt;75% of trees) were eliminated from the sample to avoid shade measurements with abundant downed wood as a confounding factor.</li> </ul>
Replications (if applicable)	6 large, 10 medium, 14 small sites by stream type
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<ul style="list-style-type: none"> <li>• Measure = shade using hemispherical photographs at every 100 feet at center of channel <ul style="list-style-type: none"> <li>• Relative importance = shade estimated using 1-Global Site Factor averaged along the length within a plot, GSF based on June 30</li> <li>• Robustness = is an accurate measure</li> </ul> </li> <li>• Measure = cover measured by densiometer <ul style="list-style-type: none"> <li>• Relative importance = tended to over-predict shade (ave 100%), especially at higher cover levels</li> <li>• Robustness = measurement method is consistent so can be calibrated</li> </ul> </li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	<ul style="list-style-type: none"> <li>• Shade in 19 harvested = 51-89% (73% ave) and 9 unharvested = 72-95% (84% ave) (Figure 7, Table 7) <ul style="list-style-type: none"> <li>• 92% of sites had &gt;60% shade</li> </ul> </li> <li>• Shade was lower on large streams, though not statistically robust (Table 8, Figure 9)</li> <li>• Average shade was lower in all RMA prescriptions over that of unharvested stands, but differed little between each other (10-13% lower than unharvested) (Figure 10)</li> <li>• No statistically significant relationship between buffer width and shade results (though small relationship)</li> <li>• Stream shade decreased by approximately 9.1% (-1 – 29.5%) for shrub only prescriptions, whereas is decreased by 2.5% in unharvested (-0.6 - 7.7%). (Table 10)</li> <li>• No relationship with aspect, gradient, floodprone width, tree height</li> <li>• Harvest conifer had lower shade than harvested hardwood (Figure 21), but statistical difference is not likely</li> <li>• There were no differences between basal area of sites with fair (40-60%, n=2) to moderate (60-80%, n=16) shade. Approximately 80 feet from the stream, sites with high (80-100%, n=10) shade had consistently higher basal area than those with fair to moderate shade, but</li> </ul>

<b>Publication</b>	A. (Allen and Dent, 2001)
	no statistical difference. (Figure 25)
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	They addressed the fundamental drivers of shade along with prescriptions and reported statistics in a reasonable manner. I am not certain of the stream size differences or when plots were measured relative to the June 30 GSF estimate. I am not clear on how stream size influences results for harvest prescription.
Potential sources of bias or error	Low sample sizes and not having pre-treatment data limits conclusions
Effects modifiers <sup>5</sup>	<ul style="list-style-type: none"> <li>• They addressed many factors affecting the riparian zone, including: tree height, type of trees, basal area, understory vegetation, aspect.</li> <li>• They addressed some factors affecting the stream, including: stream width, gradient, aspect.</li> </ul>
Notes <sup>6</sup>	Actual shade results would have been good to have besides just summary tables so that we can make conclusions for ourselves. This is especially important in the situation where there are frequently not statistical differences.
Method references <sup>7</sup>	n/a

<b>Publication</b>	B. (Allen and Dent, 2001)
Study dates and study duration (# of years, dates within a year)	Between 1998 and 2001, single event sampling at each site during the study period
Study location (watersheds, region/state, country), settings where riparian buffers were applied	<p>Oregon Coast Range (central to northern), Oregon, USA</p> <p>Basins include: Siletz, Tillamook, Nehalem, Lower Columbia, Necanicum, Clatskanie, and Alsea</p>
Ecosystem type; plant association group; type of forest	<p>Only a general description of conifer species associated with the Coast Range georegion is provided.</p> <p>Riparian conifers include: <i>Tsuga heterophylla</i>, <i>Thuja plicata</i>, and <i>Picea sitchensis</i></p> <p><i>Pseudotsuga menziesii</i> is more common away from the stream.</p>

<b>Publication</b>	B. (Allen and Dent, 2001)
	Unharvested stands averaged 90-years old (32 to 120).  Harvested stands averaged 65-years old (35-125).
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	14 small, 10 medium, and 6 large streams  Average bankfull widths for harvested/unharvested: (10/7),( 20/19), and (32/33) feet respectively
Research question(s), hypotheses, objectives	<p><b><u>Objectives:</u></b></p> <p>1) “Document the ranges of shade conditions that occur under a variety of riparian stand structures and disturbance regimes in northeast and northwest Oregon.”</p> <p>2) “Document the relationships between shade and riparian stand structure, geomorphology, forest management, and other disturbances.”</p> <p><b><u>Questions:</u></b></p> <p>1) “What are the ranges in shade conditions over Blue Mountain and Coast Range forested streams and how do they compare between harvested and unharvested stands?”</p> <p>2) “Do particular Riparian Management Area prescriptions in harvested stands result in different average shade conditions?”</p> <p>3) What are the relationships between riparian stand characteristics and shade?</p>
Study design <sup>1</sup>	Replicated sampling, replicated controls, sampling after treatment
Pretreatment data (yes/no), # of years of pretreatment data	no
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<p>22 of 30 sites under large industrial ownership with remaining 8 split between small, private and federal ownership</p> <p>All treatment plots extended 100-feet from the ordinary high water mark on each side of the</p>

<b>Publication</b>	B. (Allen and Dent, 2001)
	<p>stream and were 50 to 1000 feet in length.</p> <p><b><u>RMA prescriptions:</u></b>  No-cut Buffer Width (n=16)</p> <p>Riparian Conifer Restoration (n=2)</p> <p>Site Specific (n=3)</p> <p>Unharvested (n=9)</p> <p><b><u>Upland Prescriptions:</u></b>  Clearcut (n=21)</p> <p>Unharvested (n=9)</p>
Replications (if applicable)	Questionable if these are considered replicates – not really treated as a replicated design
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	Percent shade (measured by hemispherical camera along stream channel): relevant, robust
Sample sizes and results with estimates of variation <sup>3</sup>	<p>30 sites, 21 harvested and 9 unharvested</p> <p>Harvested shade: 51 to 89 % - 2/3's of sites in 60 to 80 % range</p> <p>Unharvested shade: 72 to 95 % - 7 of 9 in 80 to 100 % range</p> <p>Average stream shade was 11 % less in unharvested stands than in harvested (84 versus 73 %, respectively)</p> <p>Differences relative to the unharvested sites by riparian management type varied little for</p>

<b>Publication</b>	B. (Allen and Dent, 2001)
	<p>the three prescriptions:  Riparian Conifer Restoration (n=2): -13 %  No-cut (n=16): -12 %  Site Specific (n=3): -10 %</p> <p>Buffer width did not explain differences in shade (no values given, just a plot)</p> <p>States that harvested stands had greater blowdown, but also that shade was better explained by harvest than blowdown percent (Figure 17 is blacked out – additional quantification is not possible).</p> <p>Differences between measurements that captured understory and those that did not were greater at harvested sites (9.1 versus 2.5 %, on average).</p>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	Sample sizes to compare difference in shade between riparian prescriptions are insufficient.
Potential sources of bias or error	<p>Hemispherical photo analysis is sensitive to proper setup of camera.  Error possible via resolution of camera and analysis algorithm.</p> <p>Bias introduced by intentionally eliminating sites with &gt;75 % blowdown</p>
Effects modifiers <sup>5</sup>	Effects modifiers such as topography/valley morphology, aspect, forest type and composition, and natural disturbances are addressed in this paper, but not used to adjust results of analysis pertaining to SR questions.
Notes <sup>6</sup>	The paper includes a section where a model to predict stream shade is developed. The analysis doesn't provide any additional insight on the treatment effects presented earlier in the paper, but does suggest that 65 % of the variability in stream shade can be explained by the variables Live Crown Ratio and Basal Area per Acre on the south side of the stream.
Method references <sup>7</sup>	

<b>Publication</b>	(Brazier and Brown, 1973)
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<b>Publication</b>	(Brazier and Brown, 1973)
Study dates and study duration (# of years, dates within a year)	Not stated
Study location (watersheds, region/state, country), settings where riparian buffers were applied	<ul style="list-style-type: none"> <li>• Oregon, USA</li> <li>• southern Cascades ( Little Rock, Francis, and Reynolds Creeks)</li> <li>• Coast Range (Deer, Lake, Grant, Griffith, Savage, and Needle Branch)</li> <li>• All sites with the exception of Needle Branch located in National Forests (Umpqua for the Cascades and Siuslaw for the Coast Range); Needle Branch is industrially owned</li> </ul>
Ecosystem type; plant association group; type of forest	primarily merchantable (stated “commercial”) conifers comprising riparian forests but one site with young red alder and shrub vegetation
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	“small mountain streams” is only detail on size provided
Research question(s), hypotheses, objectives	<p>OBJECTIVE (not stated directly, but inferred)</p> <p>1. Examine buffer widths, buffer timber volume, and buffer canopy density effectiveness in protecting stream temperature increases following forest harvest</p>
Study design <sup>1</sup>	<ul style="list-style-type: none"> <li>• Stream temperature measurements “above and below” clearcut (exact locations/distances not provided)</li> <li>• Angular canopy density (aligned with maximum solar angle for July/August) measured on 100-foot intervals</li> <li>• Estimated commercial timber volume within buffer</li> <li>• Average buffer strip width through clearcut estimated</li> <li>•</li> </ul>
Pretreatment data (yes/no), # of years of pretreatment data	No
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<ul style="list-style-type: none"> <li>• Clearcut with buffer strips of varying widths and species composition (although species effect not directly assessed)</li> </ul>

<b>Publication</b>	(Brazier and Brown, 1973)
Replications (if applicable)	No
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<ul style="list-style-type: none"> <li>• Measure = Stream Temperature <ul style="list-style-type: none"> <li>• Relative importance = High</li> <li>• Robustness = High (resolution for early-70's measurements?)</li> </ul> </li> <li>• Measure = Angular Canopy Density <ul style="list-style-type: none"> <li>• Relative importance = High</li> <li>• Robustness = Somewhat robust (user-subjectivity similar to densiometer)</li> <li>•</li> </ul> </li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	<ul style="list-style-type: none"> <li>• Upstream-to-downstream temperature increases ranged from 0.6 to 5.0 C and followed a generally decreasing trend with increasing buffer width (n=11)</li> <li>• The lowest increase was found for both 60-foot and 100-foot buffers (a different 100-foot buffer had an increase of 2.2 C)</li> <li>• The maximum increase was for an eight foot buffer of young <i>Alnus rubra</i> saplings</li> <li>• Maximum angular canopy density of 80 % is achieved at a buffer width of 80 feet; 90 % of the maximum is achieved with a 55-feet wide buffer (n appears to equal 13, but no explanation given for additional data points; Figure 5)</li> </ul>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	Strength of statistical relationship relating angular canopy density to buffer strip width questioned as regression assumptions do not appear to have been met and considerable scatter around prediction.
Potential sources of bias or error	<ul style="list-style-type: none"> <li>• Did not account for aspect, buffer age (one buffer was young alder), distribution of vegetation types on each side of the buffer (at least one stream had no conifers on south side of the buffer), or understory composition</li> </ul>
Effects modifiers <sup>5</sup>	Assessed the influence of buffer strip timber volume, buffer strip width, and angular canopy density as effects modifiers.
Notes <sup>6</sup>	.
Method references <sup>7</sup>	

<b>Publication</b>	(Brosofske et al., 1997)
Study dates and study duration (# of years, dates within a year)	2 years: 9 sites summer of 1993, 5 resampled in summer 1994; additional 6 sites summer of 1994 Summer = 1-2 weeks within window of end of June through August
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Washington – foothills of western Cascade Mountains, elevations 150-600 m
Ecosystem type; plant association group; type of forest	“Overstory vegetation at the study sites is comprised primarily of Douglas-fir ( <i>Pseudotsuga menziesii</i> [Mirb.] Franco) and western hemlock ( <i>Tsuga heterophylla</i> [Raf.] Sarg.), with occasional red alder ( <i>Alnus rubra</i> Bong.), western red cedar ( <i>Thuja plicata</i> Donn), and grand fir ( <i>Abies grandis</i> [Dougl.] Lindl.). Ground vegetation is diverse, composed of both lowland and upland species.”
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	Width between 2-4 m
Research question(s), hypotheses, objectives	“Specific objectives of this paper are: (1) to characterize pre-harvest riparian microclimatic gradients from the stream to the upland; (2) to identify the effects of harvesting on these gradients; and (3) to describe the effects of buffer width and nearstream microclimate on stream microclimate.”
Study design <sup>1</sup>	<ul style="list-style-type: none"> <li>• Sampling at six 50 m stations along a 300 m transect perpendicular to the stream, only 1 measure at the stream center where water temperature was measured (no details to depth or method). Air, surface and soil temperatures were measured along with relative humidity, wind speed and solar radiation. Measures above the surface were 2 m from the surface.</li> <li>• Average dominant tree height between 25 and 50 m, canopy coverage 70-80%</li> </ul>
Pretreatment data (yes/no), # of years of pretreatment data	5 sites with 1 week of pretreatment data
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<ul style="list-style-type: none"> <li>• 15 sites: <ul style="list-style-type: none"> <li>• 4 sites harvested/planted 1990-1991 with buffers of 12-23 m</li> <li>• 5 sites have pretreatment (1993) and post-treatment (1994) data, with buffers 17-72</li> </ul> </li> </ul>

<b>Publication</b>	(Brosofske et al., 1997)
	<p>m</p> <ul style="list-style-type: none"> <li>6 sites were cut 1-4 years before monitoring in 1994, 1 with no buffer and others 10-72 m</li> </ul> <p>Harvest was clearcut with buffer on all sites but one with no buffer.</p>
Replications (if applicable)	None, unless considering spatial replication.
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<p>Measures: air, surface, stream and soil temperatures, relative humidity, wind speed and solar radiation</p> <ul style="list-style-type: none"> <li>Importance: Common microclimate measures, direct measures of microclimate</li> <li>Robustness: Stream temperature measure was not explained in enough detail to make a determination of robustness.</li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	<ul style="list-style-type: none"> <li>No clear pattern in stream temperature at the sites. At the site with no buffer, stream temperature was higher than all other sites.</li> <li>Regression between stream water temperature and microclimate variables showed no significant relationship between stream water temperature and wind speed, relative humidity and solar radiation; intermediate effects of air and surface temperatures (<math>R^2 = 0.20-0.70</math>); and strong effects of soil temperature (<math>R^2 = 0.75-0.98</math>) (especially at pre-harvest sites) (Figure 9).</li> <li>Soil temperature indicated no significant difference pre- vs. post-harvest within 50 m of the stream, though there was an increase in by 25% in soil temperatures outside of the buffer (Fig 3).</li> <li>Increased air temperatures found within 50 m of the stream pre-harvest vs. post-harvest (difference of &lt;1 degree C; approximately 22.5%) (Figure 2).</li> <li>Solar radiation significantly higher (difference of <math>\sim 0.1 \text{ kW/m}^2</math>) post-harvest during the day throughout the buffer (Figure 5).</li> </ul>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	Many concerns around reliability of stream temperature data – no replication in the channel to determine whether the stream measure is characteristic, only 1-2 weeks of stream temperature data taken at just one window with no replication.
Potential sources of bias or error	Regressions of stream temperature vs. microclimate measures is straight-forward, though there was no indication of how time series effects were dealt with.

<b>Publication</b>	(Brosofske et al., 1997)
Effects modifiers <sup>5</sup>	<ul style="list-style-type: none"> <li>• Direct comparisons: air temperature</li> <li>• Indirect comparisons: buffer width</li> <li>• Factors collected but not discussed: time since harvest, tree height, aspect</li> </ul>
Notes <sup>6</sup>	Most of this study was focused on microclimate factors and they suggest at the end that a very wide buffer ( $\geq 300$ m) may be necessary to reduce influence on all microclimate measures described in this study.
Method references <sup>7</sup>	
<b>Publication</b>	(Danehy et al., 2007)
Study dates and study duration (# of years, dates within a year)	15-day period in August 2003
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Coast Range, Oregon Elevations between 298 and 614 m
Ecosystem type; plant association group; type of forest	Douglas-fir dominant
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	Small streams with bankfull width around 1-2 m “All but one site had base flow discharge of less than a liter per second, with treatment means ranging from 0.33 to 0.69 l/s (Table 1).”
Research question(s), hypotheses, objectives	“Our objectives were (1) to describe and compare the structure of diatom and macroinvertebrate assemblages in headwater streams, (2) to identify environmental factors associated with assemblage structure, and (3) to determine the extent these factors vary among harvest prescriptions (thinning and clearcutting).”
Study design <sup>1</sup>	<ul style="list-style-type: none"> <li>• Stream temperature measures at four locations along each study reach for the same 15-day period using thermocouples inserted into the substrate (8 cm depth).</li> <li>• Hemispherical photographs taken at stream center at four locations along each reach after leaf out.</li> </ul>
Pretreatment data (yes/no), # of years	None

Publication	(Brosofske et al., 1997)																											
of pretreatment data																												
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<ul style="list-style-type: none"><li>6 mature – no harvest for at least 50 years; all second-growth</li><li>7 thinned – target of ~200 trees/hectare (initially 500-750 trees/hectare); no harvest in 15 m buffer</li></ul>																											
Replications (if applicable)	6 spatial controls																											
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<p>Thermal maxima (°C):</p> <ul style="list-style-type: none"><li>Importance: fairly commonly used measure therefore usually comparable</li><li>Robustness: uncertain due to the nature of this particular measure. Sensors were embedded within the substrate and there was no discussion of variation and how this compares to the typical variation observed for stream temperature measures.</li></ul> <p>Thermal maximum minima (°C):</p> <ul style="list-style-type: none"><li>Importance: a method for standardizing across sites</li><li>Robustness: This value should be more robust than thermal maxima.</li></ul>																											
Sample sizes and results with estimates of variation <sup>3</sup>	<table><tr><td>Table 1:</td><td>Mature Mean (SE)</td><td>Thinned Mean (SE)</td><td>Clearcut Mean (SE)</td></tr><tr><td>ANOVA P</td><td></td><td></td><td></td></tr><tr><td></td><td>6 samples</td><td>7 samples</td><td>5 samples</td></tr><tr><td>Thermal maxima (°C)</td><td>13.35 (0.40)</td><td>13.37 (0.59)</td><td>14.6 (0.55)</td><td>0.23</td></tr><tr><td>Thermal maximum minima (°C)</td><td>11.37 (0.26)</td><td></td><td>11.46 (0.48)</td><td>11 (0.88)</td></tr><tr><td></td><td>0.81</td><td></td><td></td><td></td></tr></table>	Table 1:	Mature Mean (SE)	Thinned Mean (SE)	Clearcut Mean (SE)	ANOVA P					6 samples	7 samples	5 samples	Thermal maxima (°C)	13.35 (0.40)	13.37 (0.59)	14.6 (0.55)	0.23	Thermal maximum minima (°C)	11.37 (0.26)		11.46 (0.48)	11 (0.88)		0.81			
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Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	Sample sizes are very small; therefore results could be biased. Statistics include clearcut samples, so results may be somewhat different for a comparison of mature vs. thinned stands.																											
Potential sources of bias or error	<ul style="list-style-type: none"><li>Abiotic factors were assessed with a simple ANOVA, which is robust for three-way comparisons of this nature.</li><li>Not certain how time series were dealt with, nor how the four sampling locations at a site were compiled.</li></ul>																											
Effects modifiers <sup>5</sup>	Direct measures: woody debris, gradient, substrate, discharge, groundwater (springs and																											

<b>Publication</b>	(Brosofske et al., 1997)
	seeps), stream width/depth, morphology
Notes <sup>6</sup>	Cannot make direct comparisons of stream temperature findings in this study to most other studies because stream temperature was measured within the substrate to reduce influence of loss of surface flow and solar insolation on the sensor.
Method references <sup>7</sup>	
<b>Publication</b>	(Dent, 2001)
Study dates and study duration (# of years, dates within a year)	2 years, unknown dates but assume some time around 2008
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Study contained sites across Oregon. This review focused on data from the Coast Range, West Cascades and Interior regions.
Ecosystem type; plant association group; type of forest	<ul style="list-style-type: none"> <li>• Coast Range: “Riparian areas are typically dominated by an alder overstory and a salmonberry/sword fern understory. Riparian conifer species typically include western hemlock, western redcedar, and/or Sitka spruce. Douglas-fir is more prevalent farther away from the stream.”</li> <li>• Interior: “Riparian areas on the westside of the valley are similar to those of the Coast Range with alder-dominated stands and patchy Douglas-fir. Conifers are more common in the riparian overstory on the east-side of the valley.”</li> <li>• West Cascades: “The dominant riparian tree species are red alder, western hemlock, western redcedar, and Douglas-fir. Noble fir, white fir, grand fir and Pacific fir grow at higher elevations.”</li> </ul>
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	<ul style="list-style-type: none"> <li>• Based on FPA standards: “small (&lt; 2 cfs), medium (&gt; 2cfs and &lt; 10 cfs), or large (&gt; 10cfs)”</li> <li>• Coast Range: 8 small, 2 medium, 4 large</li> <li>• Interior: 4 small, 5 medium, 3 large</li> <li>• West Cascade: 4 large</li> </ul>
Research question(s), hypotheses, objectives	Overarching question: “Are the new (1994) forest practices regulations effectively maintaining and promoting riparian conditions that will achieve the desired future condition?”

<b>Publication</b>	(Brosofske et al., 1997)
	<p>Specific questions: “1. Do estimates of average basal area that were used to craft the standard targets for basal area accurately represent mature riparian forests?  2. Do hardwoods dominate the near-stream area on all stream sizes?  3. How does the available basal area in riparian management areas compare to standard targets?  4. Are the 1994 forest practices riparian rules effective in maintaining potential sources of large wood recruitment for in-stream habitat as compared with pre-harvest condition?  <b>5. Are the 1994 stream protection rules effective in maintaining stream shade as compared with pre-harvest condition?</b>  6. What are the trends in conifer regeneration within riparian areas?”</p>
Study design <sup>1</sup>	<ul style="list-style-type: none"> <li>• Pre-treatment data collected at 40 sites, 25 were visited 1year later after harvest.</li> <li>• “Riparian sample sites were 500 ft long by 100 ft wide, running parallel to the stream. The plot location was placed at a randomized distance from the bottom of the unit. The plot was located on the left side of the stream if both sides were to be harvested.”</li> <li>• “Shade and cover were measured along five evenly spaced transects (one every 100 feet) starting at one end of the plot. Cover was measured with a convex densiometer at all five transects at midchannel and on both banks. Shade was measured with a Solar Pathfinder at the upstream, downstream, and middle transects.”</li> </ul>
Pretreatment data (yes/no), # of years of pretreatment data	1 year, 40 samples, 21 sites
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<ul style="list-style-type: none"> <li>• Prescriptions: (see Table 2 for more detail on size-prescription combinations): <ul style="list-style-type: none"> <li>• Coast Range: 4 riparian conifer restoration, 1 standard target, 3 unknown, 6 not harvested</li> <li>• Interior: 7 standard target, 2 no-cut RMA, 1 unknown, 2 not harvested</li> <li>• West Cascades: 1 standard target, 2 no-cut RMA, 1 not harvested</li> </ul> </li> <li>• Riparian Conifer Restoration (RCR) - conversion (maximum 500 feet long, can harvest all trees to within 10 feet of the stream and must replant conifers) and retention blocks (minimum 200 feet long, harvest depends on whether standard basal area target is met)</li> <li>• Standard Target – depending on region target, “harvest to the standard target while retaining a 20-foot no-cut buffer, and a specified minimum number of trees per 1000 feet of stream length, which also varies by stream size”</li> </ul>
Replications (if applicable)	Replication by Geographic Region, stream size and prescription; therefore, no replicates to 2

<b>Publication</b>	(Brosofske et al., 1997)
	replicates.
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<p>Cover: percent of sky covered by vegetation or topography</p> <ul style="list-style-type: none"> <li>• Importance: Frequently used as a surrogate for describing shade, though is not equivalent. This study drew the distinction between the two.</li> <li>• Robustness: Repeatability of +/- 10% is reasonable for method used. No reference to understory in the text makes it challenging to understand what was measured.</li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	<ul style="list-style-type: none"> <li>• Reductions in cover of were seen in) (Figure 14): <ul style="list-style-type: none"> <li>• 7 out of 9 small streams, 4 exceeded 10% (average of 12% reduction, significant p=0.03)</li> <li>• 4 of 7 medium streams, 2 exceeded 10% (average of 7% reduction)</li> <li>• 5 out of 8 large streams though the reduction was by &lt;10% (average of 1% reduction)</li> </ul> </li> <li>• “Cover in small streams before harvesting ranged from 83 to 95%, and after harvesting, ranged from 60 to 95% (Table 6).”</li> <li>• Cover was reduced the most (up to 36%) in narrower streams (&lt;10 ft wide) (Figure 15).</li> <li>• “The two greatest reductions in cover (-36 and 34%) were observed on two out of four of the RCR sites (one medium stream and one small stream).”</li> </ul>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	Number of replicates are low and number of samples are low, especially considering the diversity of sites and variability of measure. Not very conclusive evidence of effect or of no effect.
Potential sources of bias or error	Sites were not randomly selected. Not a large sample size considering variation.
Effects modifiers <sup>5</sup>	<p>Direct comparisons of: stream width</p> <p>Indirect comparisons of: width of riparian reserve, hardwoods vs. conifers, tree/basal area retention, other riparian vegetation cover</p>
Notes <sup>6</sup>	This study covers additional material regarding hardwood and conifer retention and density within the RMA (see study questions), but only one key question relevant to this review.
Method references <sup>7</sup>	ODF protocol: <a href="http://www.odf.state.or.us/internal.htm">http://www.odf.state.or.us/internal.htm</a>

<b>Publication</b>	(Dent and Walsh, 1997)
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<b>Publication</b>	(Dent and Walsh, 1997)
Study dates and study duration (# of years, dates within a year)	July through September 1995 (Brush Creek study 1994-1996)
Study location (watersheds, region/state, country), settings where riparian buffers were applied	8 of 13 were in Coast Range; 5 of 13 were in “Interior” which is the Willamette Valley foothills and interior Umpqua basin
Ecosystem type; plant association group; type of forest	Not described
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	8 medium, 3 large and 2 small (in Coast Range: 5 medium, 1 large and 2 small; in Interior 2 large and 3 medium) Wetted widths ranged from 2 to 26 feet
Research question(s), hypotheses, objectives	Objectives: “Investigate stream and riparian characteristics which influence stream temperature. Test the effectiveness of riparian management areas and hardwood conversions in maintaining stream temperature at a site and a watershed level. Determine if riparian management areas and hardwood conversions maintain stream temperatures at or below the Department of Environmental Quality (DEQ) state standard for water quality.”
Study design <sup>1</sup>	<ul style="list-style-type: none"> <li>• 13 streams</li> <li>• “Stream temperatures were used from three stations on each stream: station 1, on the upstream boundary of the harvest unit; station 2, on the downstream boundary of the harvest unit; and station 3, 1000 feet downstream of the harvest unit”</li> <li>• “Temperature data were collected every 48 minutes using HOBO-temp monitoring thermistors.”</li> </ul>
Pretreatment data (yes/no), # of years of pretreatment data	none
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single	<ul style="list-style-type: none"> <li>• 13 streams harvested with either a riparian management area (5 sites/3 sites Coast Range) or a hardwood conversion (8 sites/5 sites Coast Range)</li> <li>• “...three sites (2 sites coast range) harvested under the HWC rule were intentionally designed to limit openings on the south side of the streams.” (i.e., buffer on one side of stream)</li> </ul>

<b>Publication</b>	(Dent and Walsh, 1997)
sides of streams)	<ul style="list-style-type: none"> <li>• Sites had “intact riparian condition 1000 feet upstream and 1000 feet downstream of the harvest unit, and harvesting conducted under the 1994 stream rules....Harvest units vary between 1100 feet to nearly one mile in length.”</li> <li>• “Buffer widths varied from 18 feet to 131 feet.”</li> </ul>
Replications (if applicable)	13 sites
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<p>7-day moving mean of daily maximum, minimum and average; diurnal fluctuation</p> <ul style="list-style-type: none"> <li>• Importance: widely accepted measure</li> <li>• Robustness: collection of measures appears to be accurate, though there are four streams with missing data at one station and two streams where the third station is considerably further downstream than the other sites (one 2.4 miles and seems like it should not be used for analysis)</li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	<ul style="list-style-type: none"> <li>• Average increase in stream temperature from up to downstream station for the highest 7DMax period (July 31-Aug 6) was 2.5 °F for HWC and 2.1 °F for RMAs (Figure 3). Five changed by 1 °F or less (3 HWCs, 2 RMAs) and four changed by &gt;3 °F (all HWCs) (Figures 3 and 4). Note that HWC one-sided had inconclusive results (2 sites with little change and one with substantial change). N=13</li> <li>• Of the four sites with &lt;3 °F temperature increase, three had buffers designed to remove basal area for the north side of stream and leave more on south side of stream.</li> <li>• Change in canopy cover for the HWCs = -20 to +6% (Table 3). Change in RMAs = -18 - +9 %.</li> <li>• For 2 out of 6 comparisons, as buffer width increased, 7DMaximum and Average temperature increased (Table 4).</li> <li>• No statistically significant temperature differences between upstream and downstream of harvested stream lengths, based on an analysis of residuals from equations that account for distance from divide.</li> <li>• Analysis of the raw temperature data showed stream temperatures upstream significantly lower than either of the two stations downstream of the harvest unit (n=13?, Figure 6): <ul style="list-style-type: none"> <li>• approximately 2.5 °F for upstream to immediately downstream HWCs</li> <li>• approximately 2.2 °F for upstream to 1000 feet downstream HWCs</li> <li>• approximately 2.1 °F for upstream to immediately downstream RMAs</li> </ul> </li> </ul>

<b>Publication</b>	(Dent and Walsh, 1997)
	<ul style="list-style-type: none"> <li>• approximately 1.5 °F for upstream to 1000 feet downstream RMAs</li> <li>• Diurnal fluctuation downstream of the harvest unit was 5.8 °F for intact riparian areas, 4.7 °F for RMAs and 7.5 °F for HWCs (Figure 7).</li> <li>• One example in Umpqua Basin showed increased 7DMax downstream of HWC two years post-harvest, 1.6 °F 1<sup>st</sup> year and 2.6 °F 2<sup>nd</sup> year, following a pre-harvest decrease in temperature of 1.5 °F (Figure 11).</li> </ul>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	<ul style="list-style-type: none"> <li>• Small sample sizes and a lot of variability that was not displayed on plots, therefore cannot make statistically robust comparisons.</li> <li>• No pre-harvest and no control.</li> <li>• There were concerns that measures of canopy cover were not accurate.</li> </ul>
Potential sources of bias or error	Strong correlations between temperature and physical characteristics of the stream were not adequately addressed. Assumptions were made that all streams would retain the same trend in physical characteristics, therefore they did not need to be accounted for separately.
Effects modifiers <sup>5</sup>	Direct measures and correlation analysis of: width and length of buffer, cover/shade, stream flow, aspect, elevation, gradient, width and depth, substrate and distance from divide
Notes <sup>6</sup>	Qualitative study
Method references <sup>7</sup>	

<b>Publication</b>	(Gomi et al., 2006
Study dates and study duration (# of years, dates within a year)	Spring 1997 through summer 2002 (~5.25 years of data collection for most sites)
Study location (watersheds, region/state, country), settings where riparian buffers were applied	60 km east of Vancouver, British Columbia, Canada (UBC Malcom Knapp Research Forest)
Ecosystem type; plant association group; type of forest	Second-growth Tsuga heterophylla, Thuja plicata, and Psuedotsuga menziesii approximately 30 to 40 m in height and with 70 to 90 % crown closure
Stream size (avg. annual flow,	Mean bankfull widths range from 0.5 to 4.0 m

<b>Publication</b>	(Gomi et al., 2006
contributing area, HUC, avg. wetted width, etc.)	
Research question(s), hypotheses, objectives	OBJECTIVE “...evaluate headwater stream temperature response to clearcut logging with different riparian treatments based on a replicated paired catchment design.”
Study design <sup>1</sup>	<ul style="list-style-type: none"> <li>• Replicated paired catchment design with replication of the control and three treatment types</li> <li>• The control stream catchments had not been disturbed for 80 years and were forested with second-growth conifers</li> <li>• Treatments were 10 m stream buffer on each side of the stream and 30 m buffer on each side of the stream</li> <li>• Only 20 to 25 % of the total area adjacent to the stream was clearcut, with the exception of one “No Buffer” reach which was 53 % harvested, so as to reduce the effects of increased streamflow</li> <li>• Stream temperature was measured on 192-minute intervals at the downstream end of the cutblock or control reach</li> <li>• Harvesting occurred from April 1998 to January 1999 using a cable logging system</li> <li>• Used Generalized Least Squares regression, accounting for serial autocorrelation, to assess treatment effects</li> </ul>
Pretreatment data (yes/no), # of years of pretreatment data	Yes, 1 year
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<ul style="list-style-type: none"> <li>• 100 % harvest within units/blocks located immediately upgradient of the buffer</li> <li>• Harvest units tended to be linear in most cases with the long axis paralleling the stream</li> <li>• For all treatments, both sides of the stream were harvested</li> </ul>
Replications (if applicable)	Control: n=3 10 m buffer: n=1 30 m buffer: n=2
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<ul style="list-style-type: none"> <li>• Measure = Stream temperature (daily maximum, minimum, and mean) <ul style="list-style-type: none"> <li>• Relative importance = High</li> <li>• Robustness = High</li> </ul> </li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	Text Section 3.3, Table 3, Figure 4-6  10 m buffer (n=1) <ul style="list-style-type: none"> <li>• Up to 3 °C treatment effects for daily maximum temperature measured in first, second, and fourth years after harvest, with a slightly larger (3 °C ) and more continuous and prolonged effect measured during the third year</li> </ul>

<b>Publication</b>	(Gomi et al., 2006)
	<p>after harvest (this stream was noted to become discontinuous during low flows which could have been a factor in the third year, however mean discharge at the control was second highest of the post-treatment period in the third year)</p> <p>30 m buffer (n=2)</p> <ul style="list-style-type: none"> <li>• Treatment effects were mostly less than 2°C for daily maximum stream temperature</li> <li>• Excursions beyond the upper 95 % prediction interval (~1°C) for the daily maximum treatment effects occurred only during summer months for one stream (D Creek) while they occurred more continuously for the other stream</li> </ul>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	<p>Despite a strong study design and analysis approach, this study is flawed in that some treatment reaches are downstream of other treatment reaches and/or tributaries directly affected by treatment harvests. The authors provide rationale for why they do not believe the effect of this factor is of significance in Section 4.3. However, this factor adds uncertainty to the overall results.</p> <p>Interpretation of results was difficult because of conflicting statistical significance hits for the “treatment effects” plots (Figures 4 and 5) and Table 4 that summarized summer “disturbances”.</p>
Potential sources of bias or error	<ul style="list-style-type: none"> <li>• Potential for upstream treatment reaches introducing bias and/or variability to downstream treatment-control relationships during the post-treatment period</li> <li>• Did not account for channel width: for the no buffer streams, the 4 streams were split between wide channels and narrow, incised channels which likely influenced the large variability in the response to harvest</li> <li>• Drainage area differences between treatment types could confound comparison of effects magnitude by treatment type</li> <li>• Streamflow continuity was not accounted for: for the 10 m buffer stream, the channel was noted to become “a series of poorly connected or disconnected pools” which likely affected temperature dynamics relative to the spatially-continuous control stream</li> </ul>
Effects modifiers <sup>5</sup>	<ul style="list-style-type: none"> <li>• The effect of air temperature was assessed in Figure 6.</li> <li>• Impacted area % mainly controlled for with one exception</li> <li>• Drainage area was not intentionally controlled for but generally the same within treatments (with exception of one “No Buffer” stream having ~5 times larger drainage area) , but different across treatments</li> </ul>
Notes <sup>6</sup>	<p>This study was thoughtfully planned from both statistical design and statistical analysis perspectives. However, loss of treatment streams for the 30 m and 10 m buffer types resulted in less replication than planned which reduced the confidence in the findings for the management types most relevant to this Systematic Review. Additionally, the authors attempt to reduce the effect of increased groundwater contributions and associated temperature influences as a result of forest harvest make this study less applicable to real-world harvest situations.</p>
Method references <sup>7</sup>	<p>General least squares method fully-developed in text, but adopted from Watson et al. (2001)</p>

<b>Publication</b>	(Groom et al., 2011a)
Study dates and study duration (# of years, dates within a year)	Entire study period from 2002 to 2008; temperature data collected July 1 – September 15; channel and riparian data 2 years pre-harvest and 2-years post-harvest within the study period
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Oregon Coast Range 33 sites: 18 private and 15 state forest land locations in Oregon’s north and middle Coast Range
Ecosystem type; plant association group; type of forest	<ul style="list-style-type: none"> <li>• Forests were ~50-70 years old; dominated by Douglas fir (<i>Pseudotsuga menzeisii</i>) and red alder (<i>Alnus rubra</i>); harvest or fire regenerated; lands primarily managed for timber production</li> <li>• One site had a 220 m long beaver pond</li> </ul>
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	<p>Small streams - average annual flows <math>\leq 57</math> L/s</p> <p>Medium streams - average annual flows 57 – 283 L/s</p> <p>1<sup>st</sup> – 3<sup>rd</sup> order streams</p>
Research question(s), hypotheses, objectives	<p>Objectives: “1. Identify site physical and vegetative factors, including shade, that relate to stream temperature change.</p> <p>2. Determine the magnitude of stream temperature change that results from timber harvest.</p> <p>3. Quantify riparian characteristics that predict shade retention after harvesting.”</p>
Study design <sup>1</sup>	<ul style="list-style-type: none"> <li>• 2 years pre-treatment data and 5 years post-treatment with minimum reach length of 300 m</li> <li>• Two study reaches on all streams – unharvested control reach immediately upstream of treatment reach</li> <li>• Reach sizes varied with averages of: 276 m control, 684 m treatment</li> <li>• Temperature collected hourly from July 1 – Sept 15 each year at 3 stations per stream bracketing the up and downstream ends of each reach</li> <li>• Probe placement followed OWEB protocol – shaded where temperature was relatively constant, reliable summer depth and well-mixed water column</li> <li>• Channel data collected: wetted width, bankfull width, thalweg depth and stream gradient every 60 m</li> <li>• Vegetation data collected in four 152 x 52 m plots on either side of study stream in control and</li> </ul>

<b>Publication</b>	(Groom et al., 2011a)
	treatment reaches; centered along reach
Pretreatment data (yes/no), # of years of pretreatment data	2 years pre-harvest for 31 sites
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<p>18 streams harvested according to FPA rules: RMAs are 15 m (small streams) and 21 m (medium streams) that are fish bearing, with a 6 m no cut zone; harvest in remaining RMA to a minimum basal area of 10.0 (small streams) and 22.9 (medium streams) m<sup>2</sup>/ha</p> <p>15 streams harvest according to FMP rules: RMAs are 52 m wide for all fish bearing streams, with an 8 m no cut zone; limited harvest allowed within 30 m of stream to create mature forest, but retain 124 trees/ha; additional tree retention of 25-111 conifer trees and snags/ha between 30-52 m</p>
Replications (if applicable)	33 replicate streams; similar in site characteristics (Table 5)
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<p>Stream shade: fish-eye photographs of canopy cover, middle of stream, 1 m above water, oriented north</p> <ul style="list-style-type: none"> <li>• Importance: widely considered representative of canopy shade, therefore important</li> <li>• Robustness: common method of measure whose accuracy is highly dependent on method of data collection and analysis; analysis method appears robust</li> </ul> <p>Daily maximum, mean, minimum and fluctuation stream temperature</p> <ul style="list-style-type: none"> <li>• Importance: direct measures from data logger</li> <li>• Robustness: used standard OWEB measurement protocol</li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	<p>Gradient-Shade effects model was highest ranking model for Maximum, Mean and Diel Fluctuation, followed closely by six other mixed-effects models where shade was included as one of the parameters (Table 1). Minimum was explained equally well by nearly all variables.</p> <p>When shade was at a minimum (51%), predicted temperature increased for all parameters: ~2 °C for maximum, ~1.5 °C for fluctuation, ~1 °C for mean and ~0.25 °C for minimum (Figure 2). When shade at maximum (96%), predicted temperature decreased (0 - 1.0 °C, depending on temperature measure). n=119?</p>

<b>Publication</b>	(Groom et al., 2011a)
	<p>Longer reaches exhibit higher predicted temperature (0.5- 1 °C when maximum length was 1.83 km) (Figure 2). Though for private forests, predicted temperature was higher in shorter reaches, maybe in part because shade was lower in shorter reaches (Figure 5).</p> <p>Low gradient (0.75%) displayed an increase in temperature, whereas a steep gradient (approximately 15%) showed decreases in predicted temperature (Figure 2).</p> <p>Out of n=31 sites with pre- and post-treatment data, approximately 12 sites (i.e. 39%) observed increases and 5 sites observed decreases in predicted maximum temperature, 14 sites showed no difference (Figure 3). ** Note that this observation is based on plots and not data points, so observations are approximate.</p> <p>“Following harvest, Maximum temperatures at private sites increased relative to state sites on average by 0.71 °C (Table 6, coefficient of PP, 95% CI = 0.51, 0.92). Similarly, Mean temperatures increased by 0.37 °C (0.24, 0.50), Minimum temperatures by 0.13 °C (0.03, 0.23), and Diel Fluctuation increased by 0.58 °C (0.41, 0.75).”</p> <p>“Private post-harvest shade values differed from preharvest values (mean change in Shade from 85% to 78%, <math>n_{\text{Private}} = 18</math>, <math>df = 17</math>, paired <math>t = -3.678</math>, <math>p = 0.002</math>); however, no difference was found for state site shade values pre-harvest to post-harvest (mean change in Shade from 90% to 89%, <math>n_{\text{State}} = 15</math> <math>df = 14</math>, paired <math>t = -1.150</math>, <math>p = 0.269</math>).” Harvest practices on state forests led to the same average shade pre- and post-harvest generally ranging 80-95% (Figure 4). Shade in private forests in pre-harvest (approximately 72-92%) was generally higher than in post-harvest (approximately 50-87%).</p> <p>No evidence of difference in shade if one or both banks were harvested at private sites (<math>n_{\text{SingleSide}} = 4</math>, <math>n_{\text{TwoSides}} = 14</math>, <math>df = 7.589</math>, <math>t = 1.978</math>, <math>p = 0.085</math>). Sample size for single sided harvests was low.</p>
Notes concerning study quality with evidence or reasoning behind	All results based on predicted change in temperature. Figure 3 shows the range in true values, therefore the range and/or a probability of exceedance may have been a more representative

<b>Publication</b>	(Groom et al., 2011a)
the notes <sup>4</sup>	<p>measure of the likelihood of finding an increase in temperature.</p> <p>Statistical methods appear strong and predicted temperature is likely a good representation of observed temperatures at sites. A power analysis would have helped to determine the strength of the sample size.</p> <p>Biases were well addressed by analysis method.</p>
Potential sources of bias or error	Understory shade may be under-represented by height at which stream shade measures were made.
Effects modifiers <sup>5</sup>	<p>Direct consideration of: length and width of riparian reserve, tree height, basal area, harvest on one vs. both sides of riparian reserve, live crown ratio, aspect, gradient, elevation, and watershed area</p> <p>Indirect consideration of: harvest in part of the riparian reserve, understory, and windthrow</p>
Notes <sup>6</sup>	
Method references <sup>7</sup>	Dent et al. 2008, Kaufmann and Robison 1998, Groom et al. 2011b

<b>Publication</b>	A. (Groom et al., 2011b)
Study dates and study duration (# of years, dates within a year)	33 streams in the Oregon Coast Range from 2002 to 2008
Study location (watersheds, region/state, country), settings where riparian buffers were applied	<p>16 streams were oriented east-west</p> <p>18 private and 15 state forest land locations in Oregon's north and middle Coast Range</p>
Ecosystem type; plant association group; type of forest	<p>Forests were ~50-70 years old, primarily managed for timber production.</p> <p>No beaver ponds or debris flows</p>
Stream size (avg. annual flow, contributing area, HUC, avg. wetted	<p>Small streams - average annual flows <math>\leq 57</math> L/s</p> <p>Medium streams - average annual flows 57 – 283 L/s</p>

<b>Publication</b>	A. (Groom et al., 2011b)
width, etc.)	Wetted width, gradient, depth given in Dent et al. 2008
Research question(s), hypotheses, objectives	<p>Primary study objective: “evaluate the effectiveness of private and state forest riparian rules and management strategies at meeting the state water quality stream temperature antidegradation standard in the Oregon Coast Range.”</p> <p>Secondary objective: “determine a means for assessing the regulatory criterion with empirical stream temperature data in an analysis that conformed as closely as possible to regulatory language.”</p>
Study design <sup>1</sup>	<p>Two study reaches on all streams – unharvested control reach and treatment reach</p> <p>18 streams had a downstream reach, immediately downstream of the treatment reach that was not harvested</p> <p>Reach sizes varied with averages of: 276 control, 684 treatment, 288 downstream</p> <p>Spatial control – reach immediately upstream of the harvest unit that remained unharvested during the study</p> <p>Temperature collected hourly from July 1 – Sept 15 each year at 3-4 stations per stream bracketing the up and downstream ends of each reach</p> <p>Probe placement followed OWEB protocol – shaded where temperature was relatively constant, reliable summer depth and well-mixed water column</p> <p>A subset of streams temperature probes may have been downstream of reaches that some years exhibited spatially intermittent surface flow</p> <p>Two statistical analyses: 1) determined whether reaches exceeded Protecting Cold Water (PCW) rule for specific years; 2) assessed whether exceedances were management-related</p>
Pretreatment data (yes/no), # of years	Temporal control - 2 years preharvest data for 26 sites, 1 year preharvest data at 7 sites

<b>Publication</b>	A. (Groom et al., 2011b)
of pretreatment data	
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<p>Treatment reach –clear-cut or thinned based on FPA or FMP riparian buffer width rules:</p> <p>4 were small, no harvest &lt;6 m, limited 7-15 m</p> <p>14 were medium, no harvest &lt;6 m, limited 7-21 m</p> <p>6 were small, no harvest &lt;8 m, limited 9-52 m</p> <p>9 were medium, no harvest &lt;8 m, limited 9-52 m</p> <p>Buffers widths averaged 40.4 m</p> <p>26 clear-cuts, 7 partial cuts (all on state land)</p> <p>17 harvested one bank (13 were state), 16 along both</p> <p>10 sites non-fish bearing or unknown; though timber treatment same as fish-bearing regarding buffers</p>
Replications (if applicable)	By stream size/prescription: 4 small/FPA, 14 medium/FPA, 6 small/FMP, 9 medium/FMP
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<p>Primary measure: PCW year-pair exceedance comparisons of 7DAYMAX stream temperature</p> <ul style="list-style-type: none"> <li>• Relative importance: an interesting approach to standardizing data, though unclear how frequently pre-harvest data is replicated to create the year-pair comparisons.</li> <li>• Appears to be a relatively robust approach.</li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	<p>Each site had 7-45 year-pair comparisons for a total of 614 comparisons for all three reach types (upstream, treatment, downstream) and three timings (pre-harvest, harvest, post-harvest)</p> <p>24 of 33 sites had at least one PCW year-pair exceedance and 65 (11%) of reaches exceeded PCW</p> <p>Approximately 40% of exceedances occurred in treatment reaches, approximately 27% pre-to post-harvest (Figure 4).</p>

<b>Publication</b>	A. (Groom et al., 2011b)
	Private forests - 40.1% probability that a preharvest to postharvest comparison of 2 years data will have temperature increase of >0.3 deg C (in discussion)  State forests – 8.6% exceedance probability for treatment pre-to postharvest that was not statistically different than all other comparisons (3.7%) (in discussion)
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	Statistical analysis was thorough, but results were fairly abstract. A better explanation of differing factors under the study period would have been appreciated – such as differences in air temperature. Could have benefited this review by providing some discussion of two-sided harvest vs. one-sided harvest or other parsing by buffer width.
Potential sources of bias or error	Authors did a good job at removing sources of bias or error.
Effects modifiers <sup>5</sup>	Modifiers directly considered in statistical analysis: discharge (i.e. size and a proxy for downstream in flow, gradient, width, width/depth ratios, and their substrate), ownership (i.e. buffer width and somewhat clearcut vs. partial cut, one bank vs. two banks).
Notes <sup>6</sup>	Not enough detail was given on Table 3. Would have been good to see plots of what the real data was for these sites so we could draw our own conclusions.  Authors say: “We expect the magnitude of the temperature response to harvest will additionally be affected by factors such as channel gradient [Subehi et al., 2009], aspect [Gomi et al., 2006], treatment length, channel width, elevation [Arscott et al., 2001], channel substrate, wood storage [Kasahara and Wondzell, 2003], and subsurface hydrology [Story et al., 2003].” Seems like they have the data to look at some of these factors and should report how much the magnitude might change.
Method references <sup>7</sup>	Dent et al. 2008 for stream characteristics

<b>Publication</b>	B. (Groom et al., 2011b)
Study dates and study duration (# of years, dates within a year)	Data collected from July 1 to September 15 of 2002 through 2008; overall study duration was 6 years
Study location (watersheds,	northern and middle Oregon Coast Range, Oregon, USA

<b>Publication</b>	B. (Groom et al., 2011b)
region/state, country), settings where riparian buffers were applied	
Ecosystem type; plant association group; type of forest	Forests managed for timber production ranging from 50-70 years old
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	Small ( $<57 \text{ l s}^{-1}$ mean annual flow) and medium ( $>57$ and $\leq 283 \text{ l s}^{-1}$ ); additional stream and riparian forest data provided in Dent et al. [2008]
Research question(s), hypotheses, objectives	<p><b>Primary:</b> "...evaluate effectiveness of private and state forest riparian rules and management strategies at meeting the state water quality antidegradation standard in the Oregon Coast Range."</p> <p><b>Secondary:</b> "...determine a means for assessing the regulatory criterion with empirical stream temperature data in and analysis that conformed as closely as possible to regulatory language."</p>
Study design <sup>1</sup>	Replicated sampling, control, sampling before and after treatment
Pretreatment data (yes/no), # of years of pretreatment data	<p>Yes</p> <p>Minimum of 2 years pre-treatment record required initially, but probe malfunctions and premature harvest schedules led to 7 sites only having 1 year of pretreatment data</p> <p>For the actual analysis, only 1 pretreatment year was used at a time in their year-pair comparisons. This effectively made this a 1-yr pretreatment study.</p>
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	Used both Forest Practices Act (FPA) buffers for private forests and the Northwest Oregon State Forest Management Plan (FMP) buffers for state forests. Within each of these categories, different no entry and limited entry buffer widths apply as a function of stream size classification. From Table 1, the no entry buffer was 0-6 m and 0-8 m slope distance for the FPA and FMP sites respectively. Limited entry buffers were 7-15 m on FPA sites with small streams, 7-21 m on FPA medium stream sites, and 9-52 m on FMP sites (regardless of stream size)

<b>Publication</b>	B. (Groom et al., 2011b)
	<p>26 of the 33 treatment reaches were clearcut and 7 were partial cut</p> <p>17 of the 33 were harvested on one bank only (of these 17, 13 were FMP sites) and 16 were harvested on both banks</p>
Replications (if applicable)	<p>FPA/Small: n=4</p> <p>FPA/Medium: n=14</p> <p>FMP/Small: n=6</p> <p>FMP/Medium: n=9</p>
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<p><b><u>Outcome Measure:</u></b> PCW stream temperature exceedances as 7-day moving mean of the daily max (7DAYMAX)</p> <p><b><u>Relative Importance:</u></b> The 7DAYMAX is the regulatory standard so it is of high relative importance.</p> <p><b><u>Robustness:</u></b> Based on the authors described data vetting procedure, combined with sensor accuracy (+/- 0.2° C), collection frequency (hourly), and QC checks with NIST thermometers, this outcome measure is regarded as robust.</p>
Sample sizes and results with estimates of variation <sup>3</sup>	<p>614 total year-pair comparisons, with between 7 and 45 generated at each study site</p> <p>In a raw assessment of all exceedances, the treatment reach of the pretreatment/postharvest year-pair category had the largest proportion of exceedances</p> <p>The mixed-effect effect model that best explained the differences in exceedances was the one that allowed for differences in FPA and FMP sites (the second best was the same but considered stream size as well)</p> <p>The probability of PCW exceedance was highest for the pretreatment/postharvest year-pair comparisons of FPA (private) sites (0.4 +/- 0.1) when all stream sizes were compared.</p>

<b>Publication</b>	B. (Groom et al., 2011b)
	<p>When stream size was considered, the point estimate probability of small FPA streams was higher than medium FPA streams (~0.55 versus ~0.38; it is not stated if this difference is statistically significant, but there is substantial overlap of 95% CIs as the small stream ranges from ~0.3 to ~0.78).</p> <p>When both streams sizes were considered, the probability of exceedance for all groups other than pre/post FPA was ~0.05 (+/-~0.05). Specific to the FMP sites, pre/post exceedance probability was 0.09 (no error estimate provided).</p> <p>Exceedances occurred for non-harvest comparisons (5 %).</p>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	The study quality is high. Data from multiple sites were used, serial autocorrelation was accounted for, model selection was validated using post-hoc simulations, and overall finding was clearly distinguishable.
Potential sources of bias or error	<p>Study sample size weighted more heavily to medium-size FPA streams which could potentially result in tighter prediction intervals for these sites relative to the others for the same level of variation.</p> <p>Choice in defining null model slope from year 2 in order to reduce Type II error rate produces conservative exceedance estimation.</p> <p>Incomplete seasonal data sets increased prediction intervals which further increased conservativeness (for those sites with incomplete data sets).</p> <p>More than half of the sites (17 of 33) were one-sided buffers only. This was not accounted for in the analysis and could bias the results.</p>
Effects modifiers <sup>5</sup>	<p>Stream size was directly considered.</p> <p>Ownership classification (state versus private) with differences in regulations (FMP versus FPA) essentially assessed the effect of buffer width.</p>

<b>Publication</b>	B. (Groom et al., 2011b)
	Mixed effects Model 2 was designed to also pick up effects of differences in reaches (i.e. flow, gradient, width/depth ratios, and channel substrate).
Notes <sup>6</sup>	
Method references <sup>7</sup>	Sturdevant [2008]; Burnham and Anderson [2002]

<b>Publication</b>	(Groom et al., 2013)
Study dates and study duration (# of years, dates within a year)	Up to 4 years (2002-2005) pre-harvest, 2 years post harvest; temperature collected July 1 to September 15
Study location (watersheds, region/state, country), settings where riparian buffers were applied	North and middle Oregon Coast Range Mountains
Ecosystem type; plant association group; type of forest	Forests were ~50-70 years old; dominated by Douglas fir ( <i>Pseudotsuga menzeisii</i> ) and red alder ( <i>Alnus rubra</i> ); harvest or fire regenerated; lands primarily managed for timber production
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	“Small and Medium (<56 lps and 56 ≥ but < 280 Lps average annual flow, respectively) fish-bearing streams”
Research question(s), hypotheses, objectives	<p>“This study is an example of a programmatic evaluation, as it examines the efficacy of forestry best management practices (BMPs, codified in the FPA) at meeting the numeric criteria across a geographic area.”</p> <p>Specific goals: “evaluate the efficacy of state and private forest practices at meeting the numeric criteria; and evaluate the process of applying numeric criteria to field data from a study replicated and controlled both spatially and temporally.”</p>
Study design <sup>1</sup>	<p>33 sites: 15 state forest and 18 privately owned forest</p> <ul style="list-style-type: none"> <li>• Two study reaches on all streams – unharvested control reach immediately upstream of treatment reach</li> <li>• Temperature collected hourly from July 1 – Sept 15 each year at 3 stations per stream</li> </ul>

<b>Publication</b>	(Groom et al., 2013)
	bracketing the up and downstream ends of each reach
Pretreatment data (yes/no), # of years of pretreatment data	Up to 4 years pre-treatment
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<p><u>18 private streams harvested according to FPA rules:</u> RMAs are 15 m (small streams) and 21 m (medium streams) that are fish bearing, with a 6 m no cut zone; harvest in remaining RMA to a minimum basal area of 10.0 (small streams) and 22.9 (medium streams) m<sup>2</sup>/ha</p> <ul style="list-style-type: none"> <li>• 18 clearcut</li> <li>• 4 harvest on one bank, 14 harvested on both banks</li> </ul> <p><u>15 state streams harvest according to FMP rules:</u> RMAs are 52 m wide for all fish bearing streams, with an 8 m no cut zone; limited harvest allowed within 30 m of stream to create mature forest, but retain 124 trees/ha; additional tree retention of 25-111 conifer trees and snags/ha between 30-52 m</p> <ul style="list-style-type: none"> <li>• 8 clearcut, 7 partial cut</li> <li>• 13 harvest on one bank, 2 harvested on both banks</li> </ul>
Replications (if applicable)	Up to 33 sites
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<p>7DAYMAX water temperature data</p> <ul style="list-style-type: none"> <li>• Importance: a common measure; therefore important</li> <li>• Robustness: generally considered a strong, robust measure</li> </ul> <p>Station 3 7DAYMAX temperature as a function of Station 2's 7DAYMAX temperature</p> <ul style="list-style-type: none"> <li>• Importance: a predictive model, but based on data</li> <li>• Robustness: if the variability between sites is considered large, I would think there may be some question as to the robustness of the model (even if statistics are strong)</li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	<p>Only 9 sites exceeded the 16 °C or 18 °C criteria (for their respective streams) (n=33, Table 1); 7 of which exceeded post-harvest at Station 3 (downstream-most station) and 2 of which did not exceed at Station 3, but exceeded at one of the two control stations (Figure 1).</p> <p>Of the 7 exceeding post-harvest, three exceeded pre-harvest and 4 did not exceed pre-harvest (Figure 1). Of the 4 that did not exceed pre-harvest, two exceeded upstream pre-harvest (Table 1)</p>

<b>Publication</b>	(Groom et al., 2013)
	<p>Of the 7 exceeding post-harvest, three had a statistically significant increase (1.2 °C or greater) and all were on private land.</p> <p>“The median (and maximum) temperature increase necessary to trigger a breach of the numeric criteria threshold at St. 3 was 2.5 °C (4.4 °C) and 3.6 °C (6.6 °C) for 16 °C and 18 °C thresholds, respectively.”</p>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	<p>The primary effect considered was air temperature and the state vs. private forest rules. Other aspects of the stream that could affect stream temperature were not discussed. Especially important when looking at broader impacts are the effects occurring in the upstream extents of the watershed and the influence of cold-water (or warm-water) inputs to the stream (i.e. tributaries, hyporheic exchange). These things were not considered.</p> <p>Results that were focused on were the exceedances, but no comparisons of the number of sites without effects vs. with observed effects or no-effects vs. effects.</p>
Potential sources of bias or error	Bias could be based on assumptions of similarities in groundwater inputs.
Effects modifiers <sup>5</sup>	<p>Direct effects of: air temperature, riparian buffer widths</p> <p>Indirect effects of: one side vs. two sides of riparian reserve</p>
Notes <sup>6</sup>	<p>Has not yet been peer-reviewed.</p> <p>Frequency/number of exceedances was not described clearly enough to understand whether exceedance duration would be an issue.</p>
Method references <sup>7</sup>	Groom et al. 2011a,b

<b>Publication</b>	(Hunter, 2010)
Study dates and study duration (# of years, dates within a year)	Summer months of 2003 through 2006 (4 years)
Study location (watersheds,	Western Washington (Olympic Peninsula and southwest Washington Coast Range)

<b>Publication</b>	(Hunter, 2010)
region/state, country), settings where riparian buffers were applied	
Ecosystem type; plant association group; type of forest	Riparian forests dominated by hardwoods (primarily <i>Alnus rubra</i> with some <i>Acer macrophyllum</i> ), some conifers present
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	Mean channel width ranged from 2.2 to 10.3 m (no designation defined, but assume bankfull width)
Research question(s), hypotheses, objectives	OBJECTIVES “...collect data that may help understand what effect hardwood conversion rules and alternate plans may have on water temperature.”
Study design <sup>1</sup>	<ul style="list-style-type: none"> <li>• Nine sites of varying buffer lengths, buffer widths, riparian forest composition, channel substrate, and valley segment type were studied (sites were actually chosen based on characteristics desired for a related silvicultural study)</li> <li>• Transects established on 25 m spacing beginning 50 m upstream of the harvest unit boundary and extending as far as 400 m downstream of the boundary when possible</li> <li>• Riparian conditions, canopy cover, channel dimensions, substrate, and streamflow, and stream temperature were measured at/along transects (or a subset of the transects)</li> <li>• Canopy cover was measured using hemispherical photography</li> <li>• Stream temperature was measured hourly on 75 m intervals (within buffer reach?) and at locations 50 m upstream and 50, 100, 200, and 400 m downstream of buffered harvest units during the summer months (beginning anywhere between mid-June to July 31 and ending after September 10 or the first high flow, whichever came first)</li> <li>• Forest harvesting occurred after 2 years of pre-treatment data was collected and continued for 2 years following treatment</li> </ul>
Pretreatment data (yes/no), # of years of pretreatment data	Yes, generally 2 years
Details on management action(s) (e.g., sizes and types of buffers; clearcut or	<ul style="list-style-type: none"> <li>• Clearcuts in upslope harvest units with a hardwood conversion buffer adjacent to the stream</li> </ul>

<b>Publication</b>	(Hunter, 2010)
thin on both or single sides of streams)	<ul style="list-style-type: none"> <li>• Final buffer configuration was different for each of the nine sites</li> </ul>
Replications (if applicable)	
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<ul style="list-style-type: none"> <li>• Measure = Canopy Cover as a Global Site Factor (GSF) weighted for exposure aspect and solar angle (0 is fully shaded and 1 is no shade) <ul style="list-style-type: none"> <li>• Relative importance = High as metric is related to shade</li> <li>• Robustness = High (measured directly and objectively)</li> </ul> </li> <li>• Measure = Stream Temperature (only maximum of the daily maxima provided per year) <ul style="list-style-type: none"> <li>• Relative importance = High</li> <li>• Robustness = High</li> </ul> </li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	<ul style="list-style-type: none"> <li>• 1 sample per treatment type</li> <li>• Within each treatment: <ul style="list-style-type: none"> <li>• Canopy cover measured annually at each transect (n varies by site)</li> <li>• Annual maximum of daily maxima temperature reported for each sensor (n varies by site)</li> </ul> </li> <li>• Results were variable based on treatment type</li> <li>• Typically, buffers where widths decreased below 10 m showed an increase in GSF of ~0.1 while wider buffers showed less change (0 to a few hundredths)</li> <li>• Stream temperature response varied and did not necessarily correspond to changes in mean GSF</li> <li>• Visually-notable increases in annual maximum of the daily maxima within or downstream of harvest unit were apparent for: <ul style="list-style-type: none"> <li>• two-sided buffers with widths less than 10 m at points on both sides</li> <li>• a one-sided buffer with a mean width of 15 m and less overall width variability than others</li> </ul> </li> </ul>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	Quality measurements were made in this study. However, the design is poor for determining the effects of buffer management on stream temperature and shade (primarily because each treatment was essentially unique). Also, use of only the annual maximum of the daily maxima for each sensor location is problematic as the day of the annual maximum could differ spatially and a large amount of information is lost when a season of data are

<b>Publication</b>	(Hunter, 2010)
	reduced to a single number.
Potential sources of bias or error	<ul style="list-style-type: none"> <li>• Buffer widths greater than 30 m were not measured, but categorically classed as 40 m buffers in plot of buffer width</li> <li>• Some sites had recent harvest units not associated with this study and with varying buffer widths located opposite (or nearly so) of the actual treatment unit</li> </ul>
Effects modifiers <sup>5</sup>	Channel azimuth, buffer width, surface flow continuity, channel gradient, channel substrate, drainage area, and maximum elevation were all measured and reported.
Notes <sup>6</sup>	The outcome measures reported are of high relative importance and highly robust, however the variability in buffer configuration amongst sites essentially makes this a series of 9 case studies. Individually, the case studies do not provide the ability to allow statistically-grounded inferences beyond the actual study reaches. Additionally, the use of GSF to characterize canopy cover is good conceptually because it accounts for effects modifiers. However, this factor is not explicitly linked to stream temperature response in this study so it is difficult to interpret the significance of different magnitudes of change in GSF. Finally, the reduction and presentation of the stream temperature data in this paper creates difficulty in detecting treatment effects.
Method references <sup>7</sup>	

<b>Publication</b>	(Jackson et al., 2007)
Study dates and study duration (# of years, dates within a year)	Overall study conducted from 1998 through 2001 as annual summer surveys (4-year duration). Data specific to the SR question collected in summers of 1998, 1999, and 2001.
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Washington Coast Range –Willapa Hills (Palix and Willapa River drainages), Grays Harbor (Newskah Creek drainage), and southwest portion of Olympic National Forest (Humptulips River)
Ecosystem type; plant association group; type of forest	Commercial timber, 2 <sup>nd</sup> -growth <i>Tsuga heterophylla</i> in riparian forest

<b>Publication</b>	(Jackson et al., 2007)
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	<ul style="list-style-type: none"> <li>• Non-fish-bearing streams</li> <li>• Drainage areas range from 1.1 to 10.1 hectares</li> <li>• Mean active channel widths range from 1.1 to 2.85 m</li> </ul>
Research question(s), hypotheses, objectives	<p><b>OBJECTIVE</b></p> <p>This paper sought to assess how timber harvest adjacent to first-order, non-fish-bearing streams changed canopy cover percentage for buffered streams and increased coverage by slash for unbuffered streams.</p>
Study design <sup>1</sup>	<ul style="list-style-type: none"> <li>• Before/After treatment design (no control used for the SR-specific measures, although full BACI used for other metrics)</li> <li>• Two treatment types: buffered (8-10 m two-sided buffer) and unbuffered</li> <li>• Measurements were made in a survey reach that was approximately 20 times the mean channel width (no measurement frequency within survey reach provided)</li> </ul>
Pretreatment data (yes/no), # of years of pretreatment data	Yes, 1 year
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<ul style="list-style-type: none"> <li>• Unbuffered: clearcut to streambank</li> <li>• Buffered: 8 to 10 m two-sided buffer (one instance where buffer was nonmerchantable timber)</li> </ul>
Replications (if applicable)	Four replications
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<ul style="list-style-type: none"> <li>• Measure = Canopy cover % for buffered streams <ul style="list-style-type: none"> <li>• Relative importance = High as metric is a good proxy for shade</li> <li>• Robustness = Moderately robust (measured with spherical densiometer, subject to user-bias)</li> </ul> </li> <li>• Measure = Logging slash coverage % for unbuffered streams <ul style="list-style-type: none"> <li>• Relative importance = Moderate (at least one study has associated this measure with protecting stream temperature increases after harvest, but, to my knowledge, the persistence of protection via this mechanism is not well-documented)</li> <li>• Robustness = Low (assumed that it was visually estimated – no details were provided here or in Jackson et al. 2001)</li> </ul> </li> </ul>

<b>Publication</b>	(Jackson et al., 2007)
Sample sizes and results with estimates of variation <sup>3</sup>	<ul style="list-style-type: none"> <li>• Canopy cover % was measured in 5 buffered streams (Table 4) <ul style="list-style-type: none"> <li>• Full buffer (n=3): <ul style="list-style-type: none"> <li>• pre-treatment=91%</li> <li>• 1<sup>st</sup> summer post=30%</li> <li>• 3<sup>rd</sup> summer post=41%</li> </ul> </li> <li>• Non-merchantable buffer (n=1) : <ul style="list-style-type: none"> <li>• pre-treatment=90%</li> <li>• 1<sup>st</sup> summer post=65%</li> <li>• 3<sup>rd</sup> summer post=10%</li> </ul> </li> <li>• Partial buffer (n=1) : <ul style="list-style-type: none"> <li>• pre-treatment=95%</li> <li>• 1<sup>st</sup> summer post=not measured</li> <li>• 3<sup>rd</sup> summer post=90%</li> </ul> </li> <li>• Mean buffer blowdown percent in the 3<sup>rd</sup> summer post-treatment (see sample sizes above): <ul style="list-style-type: none"> <li>• full=50%</li> <li>• non-merchantable=44%</li> <li>• partial=42%</li> </ul> </li> </ul> </li> <li>• Stream coverage by slash was measured in 7 unbuffered streams (Table 3) <ul style="list-style-type: none"> <li>• 1<sup>st</sup> summer post=46%</li> <li>• 3<sup>rd</sup> summer post=25%</li> </ul> </li> </ul>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	<p>The study authors advise caution in use of canopy cover % data as the value presented is an average of the study reach only and the streams as a whole had “patchy” buffers and blowdown within buffers. Further, neither canopy cover % or slash coverage % data were presented for the reference stream. This is particularly problematic for interpreting the results of the canopy cover % data as there was significant blowdown documented and it is therefore impossible to know what proportion of that blowdown may have occurred under fully forested conditions. There is also uncertainty regarding the spatial frequency of the canopy cover and slash cover measurements made within the study reach, so it is difficult to</p>

<b>Publication</b>	(Jackson et al., 2007)
	assess how representative the reported values are of the reach.
Potential sources of bias or error	User-bias associated with spherical densiometer
Effects modifiers <sup>5</sup>	<ul style="list-style-type: none"> <li>• Riparian buffer width was consistent for all survey reaches</li> <li>• High riparian tree density and associated high crown height and low live crown ratio was a factor in the low post-treatment canopy cover % values for the buffered streams (no stand density measurements provided however)</li> <li>• Blowdown prevalence resulted in increased understory light, which led to increased herbaceous vegetation growth near the stream that was “difficult to quantify”</li> </ul>
Notes <sup>6</sup>	This study is unique and useful in that it focuses on small, 1 <sup>st</sup> -order streams where relatively little work has been done to quantify the effects of shade on stream temperature. However, the canopy cover estimates are not completely representative of the entire stream and therefore may not be suitable for use as the basis of policy decisions.
Method references <sup>7</sup>	Jackson et al., 2001

<b>Publication</b>	(Jackson et al., 2001)
Study dates and study duration (# of years, dates within a year)	1998 through 1999, summer months
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Washington Coast Range –Willapa Hills (Palix and Willapa River drainages), Grays Harbor (Newskah Creek drainage), and southwest portion of Olympic National Forest (Humptulips River)
Ecosystem type; plant association group; type of forest	Commercial timber, 2 <sup>nd</sup> -growth <i>Tsuga heterophylla</i> in riparian forest
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	<ul style="list-style-type: none"> <li>• Non-fish-bearing streams</li> <li>• Drainage areas range from 1.1 to 8.1 hectares</li> <li>• Mean active channel widths range from 1.1 to 2.85 m</li> </ul>
Research question(s), hypotheses,	<p><b>OBJECTIVE</b></p> <p>This paper sought to assess how timber harvest adjacent to small, non-fish-bearing streams</p>

<b>Publication</b>	(Jackson et al., 2001)
objectives	affected stream temperature for buffered and unbuffered streams.
Study design <sup>1</sup>	<ul style="list-style-type: none"> <li>• Replicated, before/after, control/impact design</li> <li>• Two treatment types: buffered (average total buffer width ranged from 15 to 21 m, with shortest single-sided buffer of 2.3 m) and unbuffered</li> <li>• Stream temperature was measured in either one or two locations within the study stream (specific locations unknown- see notes below)</li> </ul>
Pretreatment data (yes/no), # of years of pretreatment data	Yes, 1 year
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<ul style="list-style-type: none"> <li>•</li> <li>• Buffered: 8 to 10 m two-sided buffer (one instance where buffer was nonmerchantable timber)</li> </ul>
Replications (if applicable)	Four replications
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<ul style="list-style-type: none"> <li>• Measure = Stream temperature (Daily Maximum) <ul style="list-style-type: none"> <li>• Relative importance = High</li> <li>• Robustness = High</li> </ul> </li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	<p>Results values presented in text are different than in Table 3. Text values are presented in normal type and table values are presented in italics.</p> <ul style="list-style-type: none"> <li>• Buffered (n=3 streams): 2 streams warmed (+1.6 and +2.4 °C / +2.0 <i>and</i> +2.6 °C) and 1 stream cooled (-0.3 °C / -0.5 °C), mean change = +1.2°C / +1.4 °C</li> <li>• Non-merchantable buffer (n=1 stream with 2 measurement locations): Both measurement locations warmed (+3.7 and +6.6 °C / +2.8 <i>and</i> +4.9 °C)</li> </ul>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	Lack of sufficient details within text reduces the overall utility of the results for the purposes of the SR. However, there is no evidence to suggest that the design and data acquisition were of low quality. The statistical analyses did not meet regression assumptions, which casts some doubt on the validity of the results (it is my experience that

<b>Publication</b>	(Jackson et al., 2001)
	this usually does not dramatically change the overall findings, but may change the magnitudes slightly).
Potential sources of bias or error	<ul style="list-style-type: none"> <li>• It is unknown if each temperature logger is subjected to the same linear stream distance of treatment- this could play a role in the variability of results.</li> <li>• Potential error in interpreting change based on analysis of differences in regression slopes results from the fact that there is little to no overlap in temperature ranges between the pre- and post-treatment data.</li> <li>• Does not appear that regression assumptions were met in every case.</li> <li>• Serial autocorrelation was not accounted for in the regression analysis.</li> <li>• Aspect and steepness not accounted for in analysis (one of the sites had significantly lower slopes relative to the others; aspect variability is unknown)</li> </ul>
Effects modifiers <sup>5</sup>	<p>None of these are specifically accounted for, but may have influenced results:</p> <ul style="list-style-type: none"> <li>• Buffer width and length</li> <li>• Canopy cover %</li> <li>• Slash cover % (discussed)</li> <li>• Crown height</li> <li>• Riparian tree density</li> <li>• Near-stream herbaceous vegetation</li> <li>• Topography</li> <li>• Aspect</li> </ul>
Notes <sup>6</sup>	<p>The final analysis only assessed the influence of riparian management on stream temperature at 11°C. While this value was chosen to remain within limits of the regression relationship as best as possible, it obscures the fact that some of the streams would have much larger impacts if assessed at temperatures just a few degrees warmer (assuming, of course, that the relationships remained linear). The regression equations are provided so it is possible to compute treatment effects at other temperatures using the methodology of the paper. Also, no information is provided as to where the temperature loggers were located and if each was exposed to the same linear distance of treatment. Therefore, it is impossible to interpret what the measured magnitude of change is per unit length of treatment.</p>

<b>Publication</b>	(Jackson et al., 2001)
Method references <sup>7</sup>	

<b>Publication</b>	(Janisch et al., 2012)
Study dates and study duration (# of years, dates within a year)	2001 through 2008 (study was not synchronous across all of the research catchment clusters) Data collection primarily in July and August
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Western Washington Coast Range– Willapa Hills and Capitol Forest areas
Ecosystem type; plant association group; type of forest	<i>Pseudotsuga menziesii</i> , <i>Tsuga heterophylla</i> , and <i>Alnus rubra</i> were dominant conifer and hardwood species Forests were even-aged within a catchment and stands ranged from 60 to 110 years old
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	<ul style="list-style-type: none"> <li>• Drainage areas ranged from 1.9 to 8.5 hectares</li> <li>• Average July and August streamflow was 0.3 L s<sup>-1</sup></li> <li>• Mean bankfull width ranged from 0.4 to 2.3 meters</li> </ul>
Research question(s), hypotheses, objectives	<p><b>OBJECTIVES</b></p> <ul style="list-style-type: none"> <li>• Test if the temperature response to clearcut logging in small, headwater streams was the same as that documented for larger streams</li> <li>• Determine if either continuous or patch buffer strips resulted in smaller temperature responses than clearcut streams</li> <li>• Evaluate whether buffer design had an influence on how well the buffer mitigated temperature response</li> </ul> <p><b>HYPOTHESIS</b></p> <ul style="list-style-type: none"> <li>• Temperature increases would be large in clearcut streams, “small and non-significant” in continuously buffered streams, and intermediate in patch-buffered streams.</li> </ul>
Study design <sup>1</sup>	<ul style="list-style-type: none"> <li>• Before-After-Control-Impact</li> </ul>

<b>Publication</b>	(Janisch et al., 2012)
	<ul style="list-style-type: none"> <li>• Research catchment clusters had one reference and several treatments</li> <li>• Within clusters, some catchments were adjacent to each other and others were within the nearby vicinity</li> <li>• Treatments for each cluster occurred during the same year, but treatment timing varied across clusters</li> <li>• Calibration data was collected for 1 to 2 summers prior to treatment</li> <li>• Post-treatment data was collected for 2 summers after logging</li> <li>• Stream temperature was measured on half-hourly or hourly intervals at the most downstream location possible without being influenced by the buffer of the larger stream it was a tributary to</li> </ul>
Pretreatment data (yes/no), # of years of pretreatment data	Yes, 1 to 2 summer seasons
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<p>Three management actions evaluated:</p> <ul style="list-style-type: none"> <li>• Clearcut entire catchment with no buffer</li> <li>• Continuous buffer - 10 to 15 m on each side of the stream with the rest of the catchment clearcut</li> <li>• Patch buffer – “portions of the riparian forest 50 to 110 meters long were retained in distinct patches...” with the remaining portion of the catchment clearcut</li> </ul>
Replications (if applicable)	<ul style="list-style-type: none"> <li>• Eight total clusters, but treatments were not balanced across clusters so cannot consider as true replicates</li> <li>• Occasional within cluster replication (two catchments maximum with same treatment)</li> </ul>
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<ul style="list-style-type: none"> <li>• Measure = Canopy and Topographic Density (CTD; measured via hemispherical photography) <ul style="list-style-type: none"> <li>• Relative importance = High</li> <li>• Robustness = High</li> </ul> </li> <li>• Measure = Stream temperature (Daily Maximum) <ul style="list-style-type: none"> <li>• Relative importance = High</li> <li>• Robustness = High</li> </ul> </li> </ul>

<b>Publication</b>	(Janisch et al., 2012)
Sample sizes and results with estimates of variation <sup>3</sup>	<p>CTD (Section 3.1.1, p. 308)</p> <ul style="list-style-type: none"> <li>• Pre-treatment average for all streams = 94%</li> <li>• Reference did not change significantly in post-treatment period (n=8)</li> <li>• Patch buffer reduced to 76% (s.e. = 5.1; n=5), statistically significant</li> <li>• Continuous buffer reduced to 86% (s.e. = 1.7; n=10), not significant</li> </ul> <p>Mean Maximum Daily Stream Temperature Response (Table 2/Figures 3 and 4; * indicates statistically significant)</p> <ul style="list-style-type: none"> <li>• Patch buffer increased by 0.73*, 0.72, and 0.84 °C, respectively (n=5)</li> <li>• Continuous buffer increased by 1.06*, 0.89*, and 0.38** °C, respectively (n=6; **statistically significant until August 15<sup>th</sup>)</li> </ul> <p>Stream Temperature Response Correlations (Table 3)</p> <ul style="list-style-type: none"> <li>• Inverse relationship with CTD (not statistically significant)</li> <li>• Positive relationships with aspect cosine, length of surface flow, and wetland area (in increasing order; statistically significant)</li> </ul>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	Overall study quality is high. Proximity of clusters allowed pre/post analysis of reference stream temperature series to ensure stationarity assumption was met. Statistical analyses accounted for serial autocorrelation and generally maximized potential of data. Small sample size restricted causal inference in correlation analysis.
Potential sources of bias or error	<ul style="list-style-type: none"> <li>• Small sample sizes increase potential for Type II error in this analysis (false negative).</li> <li>• CTD determination was made with widely-spaced photographs relative to the stream size (40 to 80 m apart).</li> <li>• Unbalanced implementation of treatments across sites could introduce location/cluster bias (i.e. having two treatments at one site and one at the others means that if the response that the two-treatment site was uniform and different from the others, it would have a disproportionate effect on the overall result).</li> </ul>
Effects modifiers <sup>5</sup>	The following effects modifiers were evaluated for correlation with magnitude of mean daily temperature responses for the first year following harvest (see Table 3):

Publication	(Janisch et al., 2012)
	<ul style="list-style-type: none"> <li>• Elevation</li> <li>• Catchment Area</li> <li>• Aspect</li> <li>• Channel Gradient</li> <li>• Channel Length</li> <li>• Depth</li> <li>• CTD (total and only for wetted stream length upstream of temperature logger)</li> <li>• Wetland Area %</li> </ul> <p>Bankfull width and flow pereniality were also documented in the paper, but not used in the analysis.</p> <p>The theoretical influence of sediment size is addressed in the Discussion section, but not evaluated in the data.</p> <p>Variability in logging slash coverage in clearcut streams and windthrow in buffered streams is mentioned but was not accounted for in the analyses.</p> <p>Bedrock lithology was different between the two sites and could influence temperature response.</p>

<b>Publication</b>	(Janisch et al., 2012)
Notes <sup>6</sup>	The overall temperature response for the small streams measured in this study was relatively small, particularly for the clearcut stream. Although the data analysis was well-planned, the results were not fully presented. Therefore, some facets of the results were not discernible. One point mentioned in the Discussion section was that within treatments the responses were highly variable. This is likely a function of the variability in streamflow generation processes and overall catchment heterogeneity at this scale and fits well with the representative elementary area concept (where these catchments are smaller than the threshold for stream temperature response). The management implication is that there is no one size fits all prescription to protect stream temperature at this scale. On the other hand, even the clearcut streams did not have a large temperature response (maximum increase measured on a single day was 3.6 °C).
Method references <sup>7</sup>	

<b>Publication</b>	(Kiffney et al., 2003)
Study dates and study duration (# of years, dates within a year)	November 1997 to October 1999
Study location (watersheds, region/state, country), settings where riparian buffers were applied	<ul style="list-style-type: none"> <li>• 45 km east of Vancouver, British Columbia, Canada</li> <li>• UBC Malcom Knapp Research Forest – Maple Ridge</li> <li>• “Coast Range of the Pacific Coastal ecoregion”</li> </ul>
Ecosystem type; plant association group; type of forest	<ul style="list-style-type: none"> <li>• Coastal western hemlock biogeoclimatic zone</li> <li>• Dominant forest tree species: <i>Tsuga heterophylla</i>, <i>Thuja plicata</i>, and <i>Psuedotsuga menziesii</i></li> <li>• Broadleaf riparian species: <i>Populus trichocarpa</i>, <i>Alnus rubra</i>, <i>Acer circinatum</i>, and <i>Rubus spectabilis</i></li> <li>• Generally “second-growth, fire-initiated forest approximately 70 years old (mean height = 45 m)</li> </ul>
Stream size (avg. annual flow, contributing area, HUC, avg. wetted	<ul style="list-style-type: none"> <li>• 1<sup>st</sup>- and 2<sup>nd</sup>-order streams</li> <li>• Drainage areas range from 12 to 84 hectares</li> </ul>

<b>Publication</b>	(Kiffney et al., 2003)
width, etc.)	<ul style="list-style-type: none"> <li>• Summer baseflow discharge ranges from 0.03 to 3.2 L s<sup>-1</sup></li> </ul>
Research question(s), hypotheses, objectives	<p>RESEARCH QUESTIONS</p> <ul style="list-style-type: none"> <li>• How does riparian buffer width influence biota as a result of changes in light and water temperature?</li> <li>• “Was there a buffer width that had no detectable effect on these response variables?”</li> </ul>
Study design <sup>1</sup>	<ul style="list-style-type: none"> <li>• 13 stream reaches were included in the study</li> <li>• Each reach was designated as one of three different treatments (described below) or a control</li> <li>• Stream temperature was measured on hourly intervals (location not specified but see Gomi <i>et al.</i>, 2006 for additional details)</li> <li>• Photosynthetically-active radiation (PAR) was measured directly above the water surface at 6 to 9 “random locations within each study reach” once or twice a month</li> </ul>
Pretreatment data (yes/no), # of years of pretreatment data	<ul style="list-style-type: none"> <li>• None used in analysis although partial pre-treatment data was collected for stream temperature (temperature loggers for a subset of locations were lost in a storm; locations not lost had 1-year of pre-treatment data)</li> </ul>
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<ul style="list-style-type: none"> <li>• Treatments were 10 m stream buffer on each side of the stream and 30 m stream buffer on each side of the stream</li> <li>• 100 % harvest within units/blocks located immediately upgradient of the buffer</li> <li>• Harvest units tended to be linear in most cases with the long axis paralleling the stream</li> <li>• For all treatments, both sides of the stream were harvested</li> </ul>
Replications (if applicable)	<p>Control: n=3  10 m buffer: n=3  30 m buffer: n=3</p>
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<ul style="list-style-type: none"> <li>• Measure = Stream temperature (daily mean and maximum) <ul style="list-style-type: none"> <li>• Relative importance = High</li> <li>• Robustness = High</li> </ul> </li> <li>• Measure = PAR at water surface (June through November) <ul style="list-style-type: none"> <li>• Relative importance = High</li> <li>• Robustness = Potentially high, but not enough detail given to ascertain</li> </ul> </li> </ul>

<b>Publication</b>	(Kiffney et al., 2003)
Sample sizes and results with estimates of variation <sup>3</sup>	<p>Stream Temperature (Results text, p. 1066; Figure 3)</p> <ul style="list-style-type: none"> <li>• Actual sample sizes not given, but are assumed to be the number of days per season times the number of replications for a given treatment/control (only the first year post-harvest was used in the analysis)</li> <li>• For both mean and maximum daily temperatures, the seasonal mean was inversely proportional to the level of protection given to the stream (i.e. clearcut&gt;10 m buffer&gt;30 m buffer&gt;reference) in winter, spring, and summer; it is important to note that not all differences between treatments were statistically significant; variability shown as 1 standard deviation of the mean is almost always larger than the difference between treatment types of the next level of protection <ul style="list-style-type: none"> <li>• The seasonal mean, mean daily water temperature for each treatment was significantly greater than the control for the winter, spring, and summer</li> <li>• The seasonal mean, maximum daily water temperature for each treatment was significantly greater than the control in spring and summer</li> <li>• For summer maximum daily temperatures, the mean for the clearcut was 4.8 °C higher than the control, the 10 m buffer was 3 °C higher, and the 30 meter was 1.6 °C higher (the response for the 30 m treatment was not statistically significant); however, there was no significant difference between the 10 m buffer and the clearcut or for the 30 m and 10 m buffers for this season</li> </ul> </li> </ul> <p>PAR (Figure 2)</p> <ul style="list-style-type: none"> <li>• Actual sample sizes for PAR are unknown (see “Study Design” section for general numbers)</li> <li>• PAR was also inversely proportional to the level of protection given to the stream <ul style="list-style-type: none"> <li>• Clearcut PAR was 58 times, 10 m buffer was 15 times, and 30 m buffer was 5 times larger than Control (all statistically significant)</li> </ul> </li> </ul>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	The study quality is moderate. Without pre-treatment data at all of the sites, natural conditions unique to each treatment or control unit with potential to affect the outcome measures cannot be accounted for in the analysis. Therefore, some unknown degree of uncertainty is inherent in the results. Additionally, the PAR measurement methodology as

<b>Publication</b>	(Kiffney et al., 2003)
	presented is potentially not as strong as systematic measurements of shade proxies that are common in other studies (see note in section below for additional detail).
Potential sources of bias or error	<ul style="list-style-type: none"> <li>• Potential for upstream treatment reaches to introduce heat to downstream treatment reach</li> <li>• Drainage area differences between treatment types could confound comparison of effects magnitude by treatment type</li> <li>• Two of the Control streams had substantially greater summer baseflow discharge than any of the treatments – this does not appear to be related to drainage area and could therefore be an indicator of larger groundwater contributions which would affect the temperature regime in these streams</li> <li>• The number of PAR measurements in each treatment reach varied from 6 to 9; it is unknown if the number of measurements was related to the length of the treatment reach; if not, representativeness would vary between treatment</li> </ul>
Effects modifiers <sup>5</sup>	<ul style="list-style-type: none"> <li>• Percent of drainage area harvested and stream length in treatment were mainly consistent with one exception for the clearcut treatment type</li> <li>• Total drainage area was not intentionally controlled for but generally the same within treatments (with exception of one clearcut stream having ~5 times larger drainage area); drainage areas were different across treatments</li> <li>• Aspect was essentially controlled for as all streams flowed north to south with one exception which flowed south to north</li> <li>• Elevation range, stream gradient, and summer baseflow discharge were also reported and could influence stream temperature</li> </ul>
Notes <sup>6</sup>	This study provides useful data for understanding the marginal benefits of increasing levels of stream protection during forest harvest. Despite an apparent increasing trend of mean or maximum temperature with level of protection, the differences are not statistically significant and are therefore not a strong basis for making management decisions.
Method references <sup>7</sup>	See Gomi et al. (2006) for additional detail on management actions and general study design

<b>Publication</b>	A. (Martin, 2004)
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<b>Publication</b>	A. (Martin, 2004)
Study dates and study duration (# of years, dates within a year)	1993-1996, during July and August
Study location (watersheds, region/state, country), settings where riparian buffers were applied	South Fork of Michael Creek drains into Michael Creek, which is a tributary to Lake Florence on Admiralty Island, Alaska
Ecosystem type; plant association group; type of forest	Spruce/hemlock forest in the lowlands and alpine vegetation in the highlands (max 4,800 ft elevation)
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	basin area is 2,532 acres (1,025 ha)
Research question(s), hypotheses, objectives	Evaluate buffer zone effectiveness in protecting water quality and fish habitat. Specific to this review: Examine the water temperature response to changes in riparian stand composition.
Study design <sup>1</sup>	<ul style="list-style-type: none"> <li>• Partial-cut riparian buffers were retained, no buffers on ephemeral streams</li> <li>• Two buffer zone study areas (designated “upper” and “lower” study reaches; 1,600 ft [488 m] and 1,200 ft [364 m] long, respectively) were retained along a 2,800-ft (852-m) reach</li> <li>• A third zone 1000 ft long in a large tributary stream to the above reach</li> <li>• Water quality monitored 2-yrs pre and 2-yrs post harvest</li> <li>• Water temperature were monitored at five stations – upstream edge of harvested (control), downstream end of upper study reach, just upstream of tributary confluence on the tributary, the last two book ended the lower study reach</li> <li>• Unharvested control upstream of the two harvested reaches</li> </ul>
Pretreatment data (yes/no), # of years of pretreatment data	Yes – 2 years pretreatment water quality; 1 year pre-treatment fish habitat; 1 year riparian conditions
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<ul style="list-style-type: none"> <li>• buffer zone treatment included the retention of a 25-ft (7.6 m) wide no-cut zone adjacent to the stream, followed by a 41-ft (12.4 m) wide partial-cut zone, where 50 percent of the trees greater than 12 inches DBH were harvested</li> <li>• Road construction began during fall 1994 and continued during part of the 1995 logging</li> </ul>

<b>Publication</b>	A. (Martin, 2004)
	season (i.e., March to November). Most of the timber in the basin was harvested during 1995, and all harvesting was completed by the end of the 1996 season. All timber harvesting adjacent to the study reaches was completed in late June of 1995.
Replications (if applicable)	2 reaches, but they were up/downstream of each other; 1 additional reach for shade study only
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<ul style="list-style-type: none"> <li>• Measure = shade by spherical densitometer (canopy density) <ul style="list-style-type: none"> <li>• Relative importance = very commonly used measure. According to Allen and Dent 2001, the shrub layer may provide more shade.</li> <li>• Robustness = robust measure, though may have a user bias (which would at least be consistent for the entire study)</li> </ul> </li> <li>• Measure = average or maximum daily stream temperature from continuous monitoring stations <ul style="list-style-type: none"> <li>• Relative importance = adjusted for autocorrelation</li> <li>• Robustness = seems like they adjusted for autocorrelation in a fair manner</li> </ul> </li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	<ul style="list-style-type: none"> <li>• N = 39 – 62 days of temperature data per station, per year</li> <li>• Shade (i.e. canopy density) before logging = 64-72%</li> <li>• Shade significantly reduced (24-38%) in all reaches (including control) post-harvest with greatest losses on the downstream end</li> <li>• Significant blowdown occurred throughout the buffer (up to 60%, with an average of 20%)</li> <li>• At the upstream reach - difference between average temperature at the upstream and downstream stations ranged from 0.06-0.07 °C pre-harvest and 0.19-0.20 °C post harvest; max similar (Fig 9)</li> <li>• At the downstream reach – difference between average temperature at the upstream and downstream stations was 0.23 °C pre-harvest and 0.30-0.31 °C post harvest; max similar (Fig 10)</li> <li>• Entire reach – difference between average temperature at the upstream and downstream station was 0.05 °C pre-harvest and 0.43-0.44 °C post harvest; max 18 °C pre-harvest and 0.60-0.64 °C post-harvest (Fig 11)</li> </ul>
Notes concerning study quality with	<ul style="list-style-type: none"> <li>• N was based on pseudoreplicates and so differences between prescriptions cannot be easily</li> </ul>

<b>Publication</b>	A. (Martin, 2004)
evidence or reasoning behind the notes <sup>4</sup>	<p>determined.</p> <ul style="list-style-type: none"> <li>• Control was downstream of logging and therefore is not a good control for stream temperature due to potential cumulative effects.</li> </ul>
Potential sources of bias or error	Should provide some explanation for air temperature comparisons from year to year. Are the lack of substantial temperature differences in the downstream reach due to 1993 data exclusion?
Effects modifiers <sup>5</sup>	Indirect Modifiers: tree density, tree harvest in part of the riparian reserve – i.e. variable width, harvest on both sides with buffer, windthrow
Notes <sup>6</sup>	<ul style="list-style-type: none"> <li>• Stream temperatures were generally cool - 13.2 °C and 15 °C</li> <li>• Upstream-downstream comparisons may not be valid due to significant changes in the tributary reach that enters halfway through the study reach.</li> <li>• Plots need to zoom in closer to the data range (i.e. minus outliers) for better review of data.</li> <li>• Better explanation needed for the anomalous temperature data, including the cause of the anomaly.</li> </ul>
Method references <sup>7</sup>	

<b>Publication</b>	B. (Martin, 2004)
Study dates and study duration (# of years, dates within a year)	<p>Total study period: 1993 through 2003, 11 years</p> <p>Temperature monitoring conducted from 1993-1996, 4 years</p>
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Lake Florence/Michael Creek Watershed, Admiralty Island, Alaska, USA
Ecosystem type; plant association group; type of forest	<p>Lowlands: Spruce/Hemlock</p> <p>Highlands: Alpine vegetation</p>
Stream size (avg. annual flow, contributing area, HUC, avg. wetted	Study area is South Fork Michael Creek (SFMC) - 1025 ha

<b>Publication</b>	B. (Martin, 2004)
width, etc.)	
Research question(s), hypotheses, objectives	<p><b><u>Objectives (temperature, riparian timber, habitat):</u></b></p> <p>1) “Examine the water temperature response to changes in riparian stand composition.”</p> <p>2) “Compile data and examine changes in riparian stand conditions over time.”</p>
Study design <sup>1</sup>	Before and after treatment, control compromised
Pretreatment data (yes/no), # of years of pretreatment data	Yes, 2 years
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<p>15.5 % of lower watershed was harvested between 1994 and 1996</p> <p>Partial cut riparian buffers retained along lower mainstem of SFMC. A 25-foot wide no-cut zone was located immediately adjacent to stream and then a 41-foot partial cut zone where 50 % of &gt;12 inch DBH trees were harvested.</p> <p>Two buffers left on SFMC (upper and lower, 1600 and 1200 feet, respectively) and one on the lower 1000 feet of Rutherford Creek.</p> <p>Pre-treatment occurred in 1993 and 1994. Road construction started in 1994 and most of the harvesting occurred in 1995 (but some continued in 1996).</p>
Replications (if applicable)	
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<p>Riparian canopy density measured with a spherical densiometer, relevant, somewhat robust</p> <p>Stream temperature measured at hourly intervals, relevant, robust</p>
Sample sizes and results with estimates of variation <sup>3</sup>	<p><b><u>Riparian canopy density:</u></b></p> <p>Station 1 (n=9): mean decreased from 72 to 47 % ( p-value=0.000)</p> <p>Upper Reach (n=15): ... 71 to 48 % ( p-value=0.000)</p> <p>Middle Reach (n=7): ... 66 to 40 % ( p-value=0.014)</p>

<b>Publication</b>	B. (Martin, 2004)
	<p data-bbox="726 240 1415 272">Lower Reach (n=12): ... 64 to 26 % ( p-value=0.000)</p> <p data-bbox="726 315 1056 347"><b><u>Temperature Response:</u></b></p> <p data-bbox="726 354 898 386"><i>Upper reach:</i></p> <p data-bbox="726 393 1890 490">daily mean temperature difference between the upstream and downstream extent of the reach increased from 0.06 and 0.07 C prior to harvest to 0.19 and 0.20 C in the postharvest years</p> <p data-bbox="726 532 1900 630">daily maximum temperature difference between the upstream and downstream extent of the reach increased from 0.06 and 0.08 C prior to harvest to 0.18 and 0.21 C in the postharvest years</p> <p data-bbox="726 672 1896 743">significant difference in daily mean and daily max using Tukey multiple comparison (alpha = 0.05) for preharvest/postharvest but not for within preharvest or within postharvest years</p> <p data-bbox="726 786 898 818"><i>Lower reach:</i></p> <p data-bbox="726 824 1837 928">daily mean temperature difference between the upstream and downstream extent of the reach increased from 0.23 C prior to harvest (1994 only) to 0.30 and 0.31 C in the postharvest years</p> <p data-bbox="726 971 1900 1042">daily maximum temperature difference between the upstream and downstream extent of the reach increased from 0.22 C prior to harvest to 0.30 and 0.35 in the postharvest years</p> <p data-bbox="726 1084 1896 1156">significant difference in daily mean and daily max using Tukey multiple comparison (alpha = 0.05) for preharvest/postharvest but not for within preharvest or within postharvest years</p> <p data-bbox="726 1198 898 1230"><i>Entire reach:</i></p> <p data-bbox="726 1237 1837 1334">daily mean temperature difference between the upstream and downstream extent of the reach increased from 0.05 C prior to harvest (1994 only) to 0.43 and 0.44 C in the postharvest years</p>

<b>Publication</b>	B. (Martin, 2004)
	<p>daily maximum temperature difference between the upstream and downstream extent of the reach increased from 0.18 C prior to harvest to 0.60 and 0.64 in the postharvest years</p> <p>significant difference in daily mean and daily max using Tukey multiple comparison (<math>\alpha = 0.05</math>) for preharvest/postharvest but not for within preharvest or within postharvest years</p>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	<p>Control reach was compromised by forest harvest activities upstream of the site.</p> <p>Even if control wasn't compromised, the treatment reach is significantly long enough that an upstream measurement point may not have the same temperature dynamics as the downstream reaches which could cause problems with interpreting changes along the full study reach.</p>
Potential sources of bias or error	<p>Data record truncation as a result of anomalous values likely affect ANOVA results (even though the data that was removed was done so to avoid artificially inflating variance).</p> <p>Harvesting upstream of control reach.</p> <p>Spherical densitometer subjectivity.</p>
Effects modifiers <sup>5</sup>	
Notes <sup>6</sup>	Decrease in riparian canopy density is attributed to blowdown during winter following harvesting rather than a direct effect of harvest.
Method references <sup>7</sup>	

<b>Publication</b>	(Morman, 1993)
Study dates and study duration (# of years, dates within a year)	Summers of 1990, 1991, 1992
Study location (watersheds,	Northwest Oregon: primarily Coast Range

<b>Publication</b>	(Morman, 1993)
region/state, country), settings where riparian buffers were applied	Southern Oregon: Umpqua region and further south - Cascades and Siskiyou
Ecosystem type; plant association group; type of forest	Primarily second-growth Mix of hardwood and conifer overstory, generally dominated by hardwood in the riparian area
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	Class I and II waters Average high water level width – 40 feet in Northwest (9-151 feet) and 28 feet in Southern (5-88 feet)
Research question(s), hypotheses, objectives	“Are forest riparian resources being effectively protected by the Forest Practices Program?”
Study design <sup>1</sup>	<ul style="list-style-type: none"> <li>• Surveyed: stream and riparian area widths, gradient, orientation, substrate, slope, pool depth, shade, conifer and hardwood overstory canopy, shrub cover, soil exposure, LWD, snags</li> <li>• Sample point and transect (6 ft wide) measures, stream surveys, timber cruises within 100 feet of stream</li> <li>• 29 units surveyed pre- and post-treatment</li> <li>• Shade measured by compass and densitometer from the mid-stream and at the same azimuth and aspect, expectation of a 10% measurement error.</li> </ul>
Pretreatment data (yes/no), # of years of pretreatment data	Yes, one year
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<ul style="list-style-type: none"> <li>• Primarily clearcut harvests, mostly on private timber lands.</li> <li>• Northwest streams: average required RMA width: 82 feet (27-100 feet); 3 logged on both sides of stream</li> <li>• Southern streams: average required RMA width: 59 feet (25-100 feet); 6 logged on both sides of stream</li> </ul>
Replications (if applicable)	1 year of pre-treatment data for 29 sites
Nature of the outcome measures used, their relative importance and	<p>Aquatic solar shading: measured by densiometer</p> <ul style="list-style-type: none"> <li>• Importance: shade is a common measure</li> </ul>

<b>Publication</b>	(Morman, 1993)
robustness <sup>2</sup>	<ul style="list-style-type: none"> <li>• Robustness: there can be a 10% measurement error or greater</li> </ul> <p>View to sky: open sky above the aquatic area in all directions measured with densitometer</p> <ul style="list-style-type: none"> <li>• Importance: a measure of exposure that has not been used frequently or is well defended in the literature, but may be able to give a qualitative understanding shade</li> <li>• Robustness: densitometer measures have a large degree of error; exposure to sky does not necessarily relate directly to significant solar radiation reaching the stream</li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	<p>Northwest Oregon aquatic shading (n=16):</p> <ul style="list-style-type: none"> <li>• Pre-treatment: 77% (10-99%)</li> <li>• Post-treatment: 62% (10-90%)</li> </ul> <p>Southern Oregon aquatic shading (n=13):</p> <ul style="list-style-type: none"> <li>• Pre-treatment: 81% (52-96%)</li> <li>• Post-treatment: 67% (37-96%)</li> </ul> <p>Some of the biggest decreases in shade (frequently &gt;20%) occurred when both sides of the stream were logged (Figures 4 &amp; 5).</p> <p>Northwest Oregon view-to-sky</p> <ul style="list-style-type: none"> <li>• Pre-treatment: 30 (100 – 3)</li> <li>• Post-treatment: 40 (100 – 6)</li> </ul> <p>Southern Oregon view-to-sky:</p> <ul style="list-style-type: none"> <li>• Pre-treatment: 29 (75 – 9)</li> <li>• Post-treatment: 40 ( 77 – 10)</li> </ul>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	No statistical analysis of differences, nor power analysis allowing us to know if differences between pre- and post-harvest could even be different. There needs to be an explanation of the 10% and 96% shading results, especially the 10% site. Assuming it is the same site, it is important to understand why it would have been selected as representative of a Northwest Oregon forest stand. This site would be especially questionable if it has a view-to-sky of 100.
Potential sources of bias or error	Samples sizes moderate to low. Unclear whether there were statistical differences between groups.

<b>Publication</b>	(Morman, 1993)
Effects modifiers <sup>5</sup>	Direct measures of: hardwood vs. conifers, shrub densities, large wood (terrestrial and aquatic), riparian area widths, volume/retention, gradient, substrate, method of tree removal, elevation
Notes <sup>6</sup>	Good notes on conditions for each individual site so statistical analysis could be conducted and more information could be pulled from the document. For example, relationships between shading for Class I and Class II streams, 1-sided vs. 2-sided harvest, hardwood vs. conifer, etc.
Method references <sup>7</sup>	

<b>Publication</b>	(Newton and Cole, 2013a)
Study dates and study duration (# of years, dates within a year)	2002-2009, up to 7 years mid-June through mid-September each year
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Western Oregon – within a 200 km radius of Corvallis, OR
Ecosystem type; plant association group; type of forest	“representative of hardwood and conifer-dominated riparian areas at low/medium elevations”
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	250 – 400 ha basins
Research question(s), hypotheses, objectives	“This research asks whether a series of clearcuts with various buffer designs along small fish-bearing streams in western Oregon 1) leads to post-harvest changes in stream temperature, 2) results in cumulative warming downstream from harvested units independent of pre-harvest natural warming trends as flowing waters move toward lower elevation and warmer climates, and 3) leads to post-harvest changes in air temperature near the stream surface.”
Study design <sup>1</sup>	“Reaches were 1800-2600 m long on each stream, divided into seven contiguous units of approximately equal length” composed of:

<b>Publication</b>	(Newton and Cole, 2013a)
	<ul style="list-style-type: none"> <li>Upstream control 250-500 m long</li> <li>Three harvest units (250-400 m) alternating with three uncut units of comparable size</li> </ul> <p>Stream temperature measured two years prior to harvest activities, and for up to five years post-harvest:</p> <ul style="list-style-type: none"> <li>Three or more thermistors placed at about 100-m intervals in each of the seven units along the entire reach length (“approximately 80 m below the upstream boundary of each unit, 30 m above the downstream boundary, and at an intermediate point equidistant between the upstream and downstream”)</li> </ul>
Pretreatment data (yes/no), # of years of pretreatment data	2 years stream temperature
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<ul style="list-style-type: none"> <li>Basin-wide management included: “three clearcut units of 10-20 ha [that] would span the stream with uncut units of comparable size between harvest units”</li> <li>Harvest units were on both sides of the stream except in the designated buffer</li> <li>Control was unharvested for five or more years</li> <li>Buffers were: <ul style="list-style-type: none"> <li>No tree – “merchantable trees were removed in the harvest unit, extending to the bank, leaving only shrubs; shrubs and other vegetation were chemically controlled beyond 3 m from the bank to facilitate regeneration”</li> <li>BMP – according to FPA for two-sided buffers with width depending on stream size (15-30 m)</li> <li>Partial – “buffers limited to all residual trees and shrubs within 12 m of the bank south of open water”, for streams oriented north-south, a 9-12 m screen was left on both sides of stream</li> </ul> </li> </ul>
Replications (if applicable)	3 replicates of no tree, 4 replicates of partial cut, 5 replicates of BMPs
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<p>Time series relationships of stream temperature daily means, minima, maxima, and diel fluctuations:</p> <ul style="list-style-type: none"> <li>Importance: commonly used measures of temperature, generally good at exposing extremes, though reporting as a time series relationship removes the ability to detect</li> </ul>

<b>Publication</b>	(Newton and Cole, 2013a)
	<p>extremes and generalizes the data for the period of interest</p> <ul style="list-style-type: none"> <li>• Robustness: not enough information regarding collection method to evaluate measures, though generally robust if sensors installed properly; analysis method appears to be robust</li> </ul> <p>7-day 24-hour moving mean maxima:</p> <ul style="list-style-type: none"> <li>• Importance: well accepted method for evaluating stream temperature</li> <li>• Robustness: similar comment as above regarding the measure; analysis method is robust but was only used qualitatively for this study</li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	<ul style="list-style-type: none"> <li>• No tree <ul style="list-style-type: none"> <li>• “Daily maxima (Figures 2-5) (<math>p &lt; 0.0001</math>), and means (<math>p &lt; 0.0078</math>), and diurnal fluctuations (<math>p &lt; 0.0001</math>) were significantly greater post-harvest in all of the no-tree units on the three streams where that harvest occurred.” (<math>n=3</math>)</li> <li>• “The no-tree units also showed significant decreases in summer minima (<math>p &lt; 0.0439</math>) after harvesting” at 2 of the 3 sites.</li> </ul> </li> <li>• “Changes above predicted values ranged up to 3.8° C for daily maxima (Table 2).”</li> <li>• BMP sites had mixed results – no change at one site, significant decrease in stream temperature means and minima post-harvest (though differences small) for one site, and significant increase in means, maxima (Figures 2 and 4) and diels at two sites (all ranges of differences in Table 2). Maximum change in maxima was 5.3 °C (Table 2).</li> <li>• Partial sites had mixed results (<math>n=4</math>) – one site had higher mean, minima, maxima and diel temperature post-harvest, maxima were lower post-harvest for 3 sites (up to 2.18 °C lower), lower diel fluctuations at two sites (up to 2.91 °C lower), and lower mean at one site (up to 0.59 °C lower) (Table 2, maxima in Figures 2-5).</li> <li>• Overall trend for the reach displayed increases in maxima post-harvest for 2 out of 4 sites (Figure 6) and for one other site if only one year post-harvest was considered. One site had lower maxima post-harvest (Figure 6). All other relationships were not significant.</li> <li>• Increases in 7DAY mean maximum temperature increased in the no tree units (<math>n=3</math>, generally by more than 1-2 °C), but smaller changes in partial and BMP sites, though changes could still be by 1 °C or more (Figure 7).</li> </ul>

<b>Publication</b>	(Newton and Cole, 2013a)
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	The opportunity for upstream harvest to increase temperatures in downstream uncut reaches makes downstream uncut reaches unfit to be true controls. Comparing differences between entry and exit temperatures may be able to account for some of the cumulative impacts; however, it is important to note that uncut reaches may display different results than a true control. Since temperatures could be warmer entering the uncut reach, there is more opportunity for a temperature decrease than in a true control reach. Evidence of this would be if the temperatures post-harvest cooled more than pre-harvest.
Potential sources of bias or error	Differences in air temperature from year to year can also influence stream temperature. This potential problem appears to be addressed in the pre-harvest data sets, but relationship of stream to air temperature post-harvest is not as clear.
Effects modifiers <sup>5</sup>	Direct effects: harvest one vs. two sides of stream, air temperature, width of riparian reserve, time since harvest, harvest on one or both sides of stream  Indirect effects: harvest method, aspect
Notes <sup>6</sup>	Many of the reported results were not backed up with figures, though results could be partially interpreted from Table 2.
Method references <sup>7</sup>	

<b>Publication</b>	(Newton and Cole, 2013b)
Study dates and study duration (# of years, dates within a year)	Used data from earlier studies, newly collected data from mid-June to mid-September of 2008 and 2009, cover estimates in July 2009
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Oregon Coast Range and western foothills of the Oregon Cascades
Ecosystem type; plant association group; type of forest	Prior to harvest, riparian areas were dominated by hardwoods, primarily red alder and bigleaf maple ( <i>Acer macrophyllum</i> Pursh), 12-27m tall.
Stream size (avg. annual flow, contributing area, HUC, avg. wetted	Small and medium sized streams Widths: 1.95- 4.16 m

<b>Publication</b>	(Newton and Cole, 2013b)
width, etc.)	
Research question(s), hypotheses, objectives	Revisit two previous studies (Zwieniecki and Newton 1999 and Dent 1995) to determine if increases in stream temperature and decreases in cover continue 14 and 17 years after harvest.
Study design <sup>1</sup>	<p>Previous Dent study to present:</p> <ul style="list-style-type: none"> <li>• four streams at least 1,460 meters long</li> <li>• “reach included an 180-m harvested reach, an uncut reach 300-700 m long, an upper 90-m harvested reach, an uncut reach 100-300 m long, a lower 90-m harvested reach, and an uncut reach of about 300 m downstream of the lowest harvested area”</li> <li>• “Stream temperatures were monitored starting June or July and continuing through September or October for five summers”</li> </ul> <p>Previous Zwieniecki and Newton (Z&amp;N) study:</p> <ul style="list-style-type: none"> <li>• 3 streams with reaches 490 m (Cascade Brush), 550 m (North Mill), and 790 m (Scheele)</li> <li>• 1 summer pre-harvest data (1994) upstream and downstream of harvest unit and first year post-treatment from June to September</li> <li>• Stream temperature collected 152 and 304 m downstream of harvest unit</li> </ul> <p>At both sites current:</p> <ul style="list-style-type: none"> <li>• Present study attempted to place thermistors close to original locations</li> <li>• Land points for plantation and buffer structure 4.6 m from bank on each side of stream at 15 m intervals in harvest units; at each point tallies of hardwood vs. conifer</li> <li>• Cover estimates (visual and densiometer) every 30 m centered midstream for harvested and uncut areas. Fisheye photographs taken within an hour of dusk or dawn when overcast. Cover estimates include conifer, hardwood and shrub 5 m on point; visual estimate of hemispherical cover; densiometer counts in four cardinal directions; and cover over stream by log, herbaceous vegetation and shrubs 5 m up and downstream of point.</li> </ul>
Pretreatment data (yes/no), # of years	1 year pre-treatment for 3 streams

<b>Publication</b>	(Newton and Cole, 2013b)
of pretreatment data	
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<p>Previous Dent study: 1993 harvest with residual buffers (15 or 21 m wide depending on stream width, both sides) associated with clearcut harvesting, interspersed with no-tree buffers</p> <p>Previous Z&amp;N study: 12 m buffer on the south side of stream (or some trees on both sides if stream runs north-south)</p>
Replications (if applicable)	2 years for recent post-harvest (n=7) and 5 years immediately post-harvest for half of the sites (n=4)
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<p>Time series relationships of daily mean, maximum and minimum summer stream temperature:</p> <ul style="list-style-type: none"> <li>• Importance: commonly used measures of temperature, generally good at exposing extremes</li> <li>• Robustness: not enough information regarding collection method to evaluate, though generally robust if installed properly</li> </ul> <p>Cover – not clear which measures of cover were used for comparison in which parts of the results</p> <ul style="list-style-type: none"> <li>• Importance: densiometer measures are a widely used method for estimating cover</li> <li>• Robustness: visual estimate can have a high degree of inaccuracy, not much explanation was given in how this was minimized to the extent possible</li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	<p>No-tree buffers (n=4):</p> <ul style="list-style-type: none"> <li>• increased temperatures downstream of harvest units vs. upstream uncut in the 5 years post-harvest (Fig 2)</li> <li>• increased temperatures 16-17 years post-harvest downstream vs. uncut upstream, but not as high as immediately post-harvest time period</li> <li>• cover was similar immediately post-harvest to 17 years post-harvest</li> </ul> <p>Partial buffer (n=3):</p> <ul style="list-style-type: none"> <li>• first year post-harvest had significant warming below harvest unit vs. above harvest unit of means and maxima and minima for one site</li> <li>• one site had slight increase in temperature maxima first year post-harvest</li> </ul>

<b>Publication</b>	(Newton and Cole, 2013b)
	<ul style="list-style-type: none"> <li>• one site unchanged temperature first year post-harvest</li> <li>• no significant temperature differences vs. pre-harvest from 2008/2009 data collection efforts</li> </ul>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	Beaver removal and damage of trees may influence results. Cover results from the Dent study area should have been reported here to be able to compare trends visually.
Potential sources of bias or error	No pre-harvest data for half of the sites. There are very small samples sizes with inconsistent sampling periods (1 year up to 4 years in a row).
Effects modifiers <sup>5</sup>	<p>Directly measured effects: types of trees, basal area retention, residual stand composition, harvest on both or one side of stream, time since harvest, aspect</p> <p>Indirectly measured effects: width of buffers, stream width</p>
Notes <sup>6</sup>	
Method references <sup>7</sup>	Dent 1995, Zwieniecki and Newton 1999, Strickler 1959

<b>Publication</b>	(Rashin et al., 1992)
Study dates and study duration (# of years, dates within a year)	Summer 1990- temperature was measured for 2 weeks at every location (measurement periods were not synchronous across sites)
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Coast Range, Puget Lowland, and Cascades ecoregions of Washington
Ecosystem type; plant association group; type of forest	Not stated
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	<ul style="list-style-type: none"> <li>• Type 2 and 3 streams (Washington classification)</li> <li>• Average bankfull width ranged from 2.4 to 15.8 m</li> <li>• Discharge ranged from 4.3 to 128 L s<sup>-1</sup> at downstream extent of study reaches</li> </ul>
Research question(s), hypotheses, objectives	<p><b>OBJECTIVES</b></p> <ul style="list-style-type: none"> <li>• “Determine the effectiveness of the BMPs (i.e. the RMZ rules) at maintaining water</li> </ul>

<b>Publication</b>	(Rashin et al., 1992)
	<p>temperatures at levels which meet the criteria for maximum allowable temperature established in state water quality standards.”</p> <ul style="list-style-type: none"> <li>• “Determine the effectiveness of the BMPs at meeting water quality criteria pertaining to incremental increases in temperature.”</li> <li>• “Evaluate the influence of various stream and riparian zone characteristics on BMP effectiveness.”</li> </ul>
Study design <sup>1</sup>	<ul style="list-style-type: none"> <li>• This study is a series of 9 individual case studies for west-side streams (all attempts to synthesize data include east-side streams so those results are not directly applicable to this SR and are therefore not included in this table)</li> <li>• Study sites were recently harvested (2 years or less) catchments with buffers that conformed to Washington standards at the time of the study</li> <li>• Measured stream temperature at upstream and downstream extents of riparian buffers</li> <li>• Measured shade with spherical densiometer on 76-m intervals within existing buffer</li> <li>• Also measured a variety of other buffer characteristics with potential to act as effects modifiers (see list in Effects Modifiers row)</li> </ul>
Pretreatment data (yes/no), # of years of pretreatment data	No
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<ul style="list-style-type: none"> <li>• The buffer types included one-sided and two-sided buffers adjacent to clearcut units (it is important to note that the one-sided buffers were only applied where one side of the stream was being harvested)</li> <li>• Buffer lengths varied from 385 to 825 m</li> <li>• Buffer widths ranged considerably: <ul style="list-style-type: none"> <li>• Mean buffer width (per side) varied from 9.1 to 17.4 m</li> <li>• Minimum buffer width (per side) ranged from 1.5 to 7.6 m</li> <li>• Maximum buffer width (per side) ranged from 15.2 to 30.1 m</li> </ul> </li> </ul>
Replications (if applicable)	
Nature of the outcome measures used, their relative importance and	<ul style="list-style-type: none"> <li>• Measure = Stream temperature (difference in upstream and downstream locations) <ul style="list-style-type: none"> <li>• Relative importance = High</li> <li>• Robustness = High</li> </ul> </li> </ul>

<b>Publication</b>	(Rashin et al., 1992)
robustness <sup>2</sup>	<ul style="list-style-type: none"> <li>• Measure = Canopy Cover (as measured by spherical densiometer) <ul style="list-style-type: none"> <li>• Relative importance = High</li> <li>• Robustness = Moderate based on user-subjectivity</li> </ul> </li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	<p>Median of the maximum daily water temperature differential for:</p> <ul style="list-style-type: none"> <li>• 2-sided buffers ranged from 1.3 to 4.6 °C (Table 1; n=3)</li> <li>• 1-sided buffers ranged from 0.1 to 1.4 °C (Table 1; n=6)</li> </ul> <p>Mean canopy cover for:</p> <ul style="list-style-type: none"> <li>• 2-sided buffers ranged from 23 to 91 % (Table 1; n=3)</li> <li>• 1-sided buffers ranged from 52 to 97 % (Table 1; n=6)</li> </ul>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	The study quality with regards to making inferences to temperature or shade response to buffer characteristics for west-side streams is generally low because no statistical analysis was performed for the desired subset of sites.
Potential sources of bias or error	<p>Thermistors had a fairly crude accuracy of 0.5 °C.</p> <p>Measurement periods were asynchronous across sites and some were measured outside of the critical summer high temperature season.</p>
Effects modifiers <sup>5</sup>	<p>The following potential effects modifiers were measured:</p> <ul style="list-style-type: none"> <li>• Air temperature</li> <li>• Groundwater inflow as difference in upstream and downstream discharge</li> <li>• Stream discharge</li> <li>• Buffer length</li> <li>• Buffer width and width variability</li> <li>• Channel gradient</li> <li>• Aspect</li> <li>• Buffer tree count per unit area</li> <li>• Percent hardwood and conifer species in buffer</li> <li>• Harvesting within buffer</li> <li>• For one-sided buffers, the stand and buffer type on the opposite side of the channel was</li> </ul>

<b>Publication</b>	(Rashin et al., 1992)
	<p>noted</p> <p>Other potential effects modifiers that were not measured or documented:</p> <ul style="list-style-type: none"> <li>• Catchment geology</li> <li>• Beaver activity within or upstream of buffer reach</li> </ul>
Notes <sup>6</sup>	This paper presents data for a series of 9 individual case studies for west-side streams. Summary tables of results and site characteristics as well as a brief text write-up of the results for each study stream are presented. The authors evaluate correlations of temperature response with buffer characteristics, but do so across both east- and west-side streams. Therefore, those results are not included in this table. The potential for extracting west-side data only and conducting multivariate analyses exists and may be a useful exercise for extending the utility of the study.
Method references <sup>7</sup>	

<b>Publication</b>	(Schuett-Hames et al., 2012)
Study dates and study duration (# of years, dates within a year)	2003 through 2008, sampling in three years (2004, 2006, and 2008)
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Western Washington western hemlock zone Includes Coast Range, Puget Lowlands, Cascades, and North Cascades ecoregions
Ecosystem type; plant association group; type of forest	Western hemlock zone
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	<ul style="list-style-type: none"> <li>• Non-fish bearing perennial streams</li> <li>• Mean bankfull width ranged from 3.0 to 11.4 feet</li> </ul>
Research question(s), hypotheses, objectives	<p><b>OVERALL OBJECTIVES</b></p> <p>“Obtain an unbiased estimate of post-harvest conditions associated with the western Washington Type Np riparian prescriptions”</p>

<b>Publication</b>	(Schuett-Hames et al., 2012)
	<ul style="list-style-type: none"> <li>• “Evaluate the magnitude and duration of change in comparison to untreated reference sites”</li> <li>• “Identify site and stand attributes (covariates) that influence response”</li> </ul> <p><b>SPECIFIC QUESTIONS</b></p> <p><i>Riparian stand response</i>  “What are the characteristics of riparian stands after application of the westside Type Np riparian prescriptions?”  “What is the magnitude and duration of change in riparian stands following application of the westside Type Np riparian prescriptions compared to un-harvested reference sites?”</p> <p><i>Channel debris loading</i>  “What amount of channel woody debris occurs in stream channels following application of the westside Type Np riparian prescriptions?”  “What is the magnitude and duration of change in channel debris following application of the westside Type Np riparian prescriptions compared to untreated reference sites?”</p> <p><i>Shade condition indicators</i>  “How much shade to the stream channel is provided by riparian stands following application of the westside Type Np riparian prescriptions?”  “What is the magnitude and duration of change in shade following application of the westside Type Np riparian prescriptions compared to untreated reference sites?”</p>
Study design <sup>1</sup>	<ul style="list-style-type: none"> <li>• Randomly selected 15 treatment sites from pool of Type Np (non-fish bearing, perennial) streams approved for harvest within the time constraints of the study</li> <li>• Each treatment site was paired with a nearby reference stream that did not have harvest activities within 100 ft</li> <li>• Treatment types contained a mixture of management types allowed for Np streams under Washington rules (details below)</li> <li>• The following metrics were measured: <ul style="list-style-type: none"> <li>• <i>Riparian stand response</i>: live trees per acre and basal area per acre via a complete</li> </ul> </li> </ul>

<b>Publication</b>	(Schuett-Hames et al., 2012)
	<p>census of all standing trees within 50 feet of the stream (3<sup>rd</sup> and 5<sup>th</sup> years only; 1<sup>st</sup> year was estimated using stand reconstruction procedure)</p> <ul style="list-style-type: none"> <li>• <i>Channel debris loading</i>: visually estimated total debris coverage over a 4-foot length of stream spanning the bankfull channel and centered on 50-foot intervals (3<sup>rd</sup> and 5<sup>th</sup> years only)</li> <li>• <i>Shade condition indicators</i>: % canopy cover was measured at systematic intervals beginning at a random point near the bottom of the survey reach using a spherical densiometer; measurements were made at waist-height facing upstream, downstream, and towards the left and right banks (4 measurements per station); understory plant shade was estimated visually in a 4-foot length of stream centered on the densiometer measurement station</li> <li>• Mann-Whitney non-parametric test used to compare means between treatment and reference sites</li> </ul>
Pretreatment data (yes/no), # of years of pretreatment data	No
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<p>Treatment types:</p> <ul style="list-style-type: none"> <li>• 50-foot wide no-cut buffer on each side of the stream (50-ft buffer patches)</li> <li>• 56-foot radius no harvest around the perennial initiation point (PIP patches)</li> </ul>
Replications (if applicable)	
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<p><i>Riparian Stand Response</i></p> <ul style="list-style-type: none"> <li>• Measure = Live trees per acre <ul style="list-style-type: none"> <li>• Relative importance = Moderate- can be related to shade</li> <li>• Robustness = High</li> </ul> </li> <li>• Measure = Basal area per acre <ul style="list-style-type: none"> <li>• Relative importance = Moderate to High- can be related to shade and some management alternatives focus on basal area retention</li> <li>• Robustness = High</li> </ul> </li> </ul> <p><i>Channel Debris Loading</i></p>

<b>Publication</b>	(Schuett-Hames et al., 2012)
	<ul style="list-style-type: none"> <li>• Measure = Total debris cover <ul style="list-style-type: none"> <li>• Relative importance = High- debris shade has been related to protection against stream temperature increases</li> <li>• Robustness = Moderate</li> </ul> </li> </ul> <p><i>Shade Condition Indicators</i></p> <ul style="list-style-type: none"> <li>• Measure = Canopy Cover (as measured by spherical densiometer) <ul style="list-style-type: none"> <li>• Relative importance = High</li> <li>• Robustness = Moderate based on user-subjectivity</li> </ul> </li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	<p>Statistical significance for the portions of the study referenced below was <math>\alpha=0.10</math></p> <p><i>Riparian Stand Response</i> (for 50-ft buffer patches and PIP patches only)</p> <ul style="list-style-type: none"> <li>• 50-ft buffer patches (n=13): <ul style="list-style-type: none"> <li>• Approximately 88 less mean trees per acre in each of the three post-harvest measurement periods relative to the control (no data on baseline differences though) – mean basal area per acre was approximately 60 ft<sup>2</sup> less in the 3<sup>rd</sup> and 5<sup>th</sup> years after harvest (-57.6 and -64.3, respectively)</li> <li>• there was a statistically significant decrease in live trees per acre between the 1<sup>st</sup> and 3<sup>rd</sup> year after harvest relative to the reference patch (-15 %)</li> <li>• the basal area change between 2006 and 2008 was not significant relative to the reference</li> </ul> </li> <li>• PIP patches (observational only, no statistics; n=3) <ul style="list-style-type: none"> <li>• Declining pattern of trees per acre and basal area per acre similar to 50-ft buffer patches but steeper decline (lost 50 % of the original density by the end of the 5-year study)</li> </ul> </li> </ul> <p><i>Channel Debris Loading</i></p> <ul style="list-style-type: none"> <li>• The 50-ft (n=13) and PIP (n=3) buffer patches did not have significantly different total debris coverage than the reference in either the 3<sup>rd</sup> or 5<sup>th</sup> year post-harvest</li> </ul>

<b>Publication</b>	(Schuett-Hames et al., 2012)
	<ul style="list-style-type: none"> <li>• 3rd-year mean coverage was 25 (14), 25 (17), and 28 (15) %, respectively with standard deviation in parentheses</li> <li>• 5th-year was similar except PIP increased to 43 (11) likely as a result of windthrow</li> </ul> <p><i>Shade Condition Indicators</i> (Tables 49, 50, and 51)</p> <ul style="list-style-type: none"> <li>• Mean total overhead cover % (standard deviation in parentheses; * indicates statistically significant difference from mean Reference value) <ul style="list-style-type: none"> <li>• Reference (n=14): 89 (4) / 93 (5) / 90 (5) for 1st, 3rd, and 5th years after harvest, respectively</li> <li>• 50-ft buffer (n=13): 76 * (16) / 81* (20) / 81* (16)</li> <li>• </li> <li>• PIP buffer (n=3): 55 (21) / 65 (13) / 62 (21) (no statistical tests performed for PIP)</li> </ul> </li> <li>• Mean channel % obscured by understory vegetation (number of samples is the same as above) <ul style="list-style-type: none"> <li>• Reference: 14 (8) / 13 (5) / 16 (17)</li> <li>• 50-ft buffer: 29* (17) / 31* (2) / 35* (21)</li> <li>• PIP buffer: 37 (26) / 30 (15) / 47 (38) (no statistical tests performed for PIP)</li> </ul> </li> </ul>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	The overall study quality is considered low to moderate. While the measurements, analysis, and presentation are all moderate to high quality, the absence of pre-treatment data in combination with relatively low sample sizes increases the likelihood of Type I and II errors.
Potential sources of bias or error	<ul style="list-style-type: none"> <li>• Error associated with the uncertainty of not knowing pre-treatment conditions</li> <li>• Potential bias and/or error from visual estimation of channel debris coverage and channel coverage by understory vegetation</li> </ul>
Effects modifiers <sup>5</sup>	<ul style="list-style-type: none"> <li>• Catchment and channel geomorphology is likely an important modifier for these sites that cover a fairly-wide geographic area.</li> <li>• Vegetation type within the riparian buffers should also influence the results but was not factored into any of the analyses (although conifer versus hardwood % is available in the</li> </ul>

<b>Publication</b>	(Schuett-Hames et al., 2012)
	report)
Notes <sup>6</sup>	The data collected in this study focuses on shade for non-fish bearing perennial streams. The paper presents a comprehensive dataset with respect to post-harvest shade for small streams covering the full range of physiographic conditions west of the crest of the Cascades in Washington. Critical data is presented in tables so that further analysis is possible.
Method references <sup>7</sup>	

<b>Publication</b>	(Steinblums et al., 1984)
Study dates and study duration (# of years, dates within a year)	Unknown, but shade measures collected during low-flow season
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Cascade Mountains of western Oregon
Ecosystem type; plant association group; type of forest	<ul style="list-style-type: none"> <li>• Dominant at low elevations: Douglas-fir (<i>Psuedostuga menziesii</i>), western hemlock (<i>Tsuga heterophylla</i>) and western redcedar (<i>Thuja plicata</i>)</li> <li>• Dominant at high elevations: noble fir (<i>Abies procera</i>), white fir (<i>A. concolor</i>), grand fir (<i>A. grandis</i>) and Pacific silver fir (<i>A. amabilis</i>)</li> </ul>
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	Unknown
Research question(s), hypotheses, objectives	Study environmental factors that affect buffer strip stability and stream shading
Study design <sup>1</sup>	<ul style="list-style-type: none"> <li>• 40 buffer strips – 400-700 feet long</li> <li>• Measured independent variables - characteristics of the buffer strip (i.e. basal area, understory species, buffer width).</li> <li>• Measured shading by estimating canopy density with an angular canopy densiometer. Densiometer was placed in stream center, oriented south, on a 1.5 foot tripod.</li> </ul>

<b>Publication</b>	(Steinblums et al., 1984)
	<ul style="list-style-type: none"> <li>• Regression analysis was conducted to relate densiometer measures to independent variables.</li> </ul>
Pretreatment data (yes/no), # of years of pretreatment data	None
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	Harvest occurred from 1 to 15 years prior to the study. Buffer widths ranged from approximately 25 feet to >140 feet (Figure 2).
Replications (if applicable)	28 shade-providing strips
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	Angular canopy density: measured as shade with a densiometer <ul style="list-style-type: none"> <li>• Importance: fairly common measure of shade</li> <li>• Robustness: concerns with reliability of densiometer data as results can range widely</li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	<ul style="list-style-type: none"> <li>• Shade along streams with buffer strips that were considered “shade-providing” averaged 51% (15-87%; n=28).</li> <li>• In 12 strips bounded on south by uncut forest, shade averaged 62% (26-85%).</li> <li>• As buffer strip width increased, canopy density increased in a curvilinear fashion (Figure 2).</li> </ul>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	No statistical analysis – focus was on determining regression equations.
Potential sources of bias or error	Densiometer measures can have a wide range of measurement error.
Effects modifiers <sup>5</sup>	Direct measures: buffer width, shrub density, aspect  Indirect measures: time since harvest, elevation
Notes <sup>6</sup>	
Method references <sup>7</sup>	Relationship between canopy density and densiometer measurements: Brazier and Brown 1973

<b>Publication</b>	(Veldhuisen and Couvelier, 2006)
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<b>Publication</b>	(Veldhuisen and Couvelier, 2006)
Study dates and study duration (# of years, dates within a year)	2001 through 2003, measurements made between June and September each year
Study location (watersheds, region/state, country), settings where riparian buffers were applied	<ul style="list-style-type: none"> <li>• Headwater tributaries of the Skagit Basin</li> <li>• northwestern Cascade mountains, Washington</li> </ul>
Ecosystem type; plant association group; type of forest	<ul style="list-style-type: none"> <li>• Western Hemlock Climax Zone</li> <li>• <i>Tsuga heterophylla</i>, <i>Pseudotsuga menziesii</i>, <i>Thuja plicata</i>, and <i>Alnus rubra</i> were prevalent riparian species across all sites</li> </ul>
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	<ul style="list-style-type: none"> <li>• Non-fish bearing perennial streams</li> <li>• Bankfull width ranged from 0.9 to 4.2 meters</li> <li>• Wetted width ranged from 0.5 to 1.9 meters</li> </ul>
Research question(s), hypotheses, objectives	<p><b>OBJECTIVES</b></p> <ul style="list-style-type: none"> <li>• “Evaluate the role of riparian logging, shade, aspect and channel dimensions in influencing segment-scale temperature change”</li> </ul>
Study design <sup>1</sup>	<ul style="list-style-type: none"> <li>• Selected non-fish bearing perennial streams in the Skagit basin that were harvested within the past 10 years</li> <li>• Stream temperature monitoring strategy varied by year in the study <ul style="list-style-type: none"> <li>• temperature either measured at upstream and downstream extents of the treatment reach (2001 and 2002) or measured upstream/downstream extents plus intermediate points on 150 meter intervals within the treatment reach (2003)</li> <li>• forested control stream segments were measured in 2002 and 2003</li> <li>• bankfull channel widths measured at each temperature monitoring location in 2001 and 2002</li> <li>• in 2003, shade (via spherical densiometer) and channel dimensions were measured at four evenly-spaced locations within each temperature measurement segment</li> </ul> </li> <li>• Upstream forest and riparian management varied across sites (See Appendix 2, 3, and 4b)</li> </ul>
Pretreatment data (yes/no), # of years of pretreatment data	No

<b>Publication</b>	(Veldhuisen and Couvelier, 2006)
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<p>3 primary management categories:</p> <ul style="list-style-type: none"> <li>• Clearcut completely within the past 10 years <ul style="list-style-type: none"> <li>• For 2002, this category included 3 streams that were completely clearcut and 3 that originally had buffers &lt;10 meters wide per side but had mostly blown down</li> </ul> </li> <li>• Harvest with buffer within the past 10 years <ul style="list-style-type: none"> <li>• Buffer widths ranged from 6 to 30 meters on each side</li> </ul> </li> <li>• Forested (mature)</li> </ul> <p>• 2 streams were put into a 4<sup>th</sup> category as they had been scoured by debris flows and were significantly different than the other categories</p>
Replications (if applicable)	
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<ul style="list-style-type: none"> <li>• Measure = Stream temperature (instantaneous maximum temperature, maximum 7-day moving average of the daily maximum (7-DAD Max), and range of the daily maxima and minima during the period of the 7-DAD Max) <ul style="list-style-type: none"> <li>• Relative importance = High</li> <li>• Robustness = High</li> </ul> </li> <li>• Measure = Shade (as measured by spherical densiometer) <ul style="list-style-type: none"> <li>• Relative importance = High</li> <li>• Robustness = Moderate</li> </ul> </li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	<ul style="list-style-type: none"> <li>• Mann-Whitney test for significant differences in temperature metric from 2002 (as measured at the bottom of the treatment reach; number of sites for forest = 5, buffer = 7, clearcut = 6, and debris flow = 2; significance level is <math>\alpha=0.10</math>; Table 3) <ul style="list-style-type: none"> <li>• Instantaneous max: no significant difference for forested&lt; buffer test, while forested&lt;clearcut and buffer&lt;clearcut were significant</li> <li>• 7-DAD Max: no significant difference for forested&lt; buffer; forested&lt;clearcut and buffer&lt;clearcut were significant</li> <li>• 7-DAD Range: forested&lt;buffer, forested&lt;clearcut, and buffer&lt;clearcut were all significant</li> </ul> </li> </ul>

<b>Publication</b>	(Veldhuisen and Couvelier, 2006)
	<ul style="list-style-type: none"> <li>• Tested for differences “between temperature responses on north and south aspects” and found no differences for all treatment categories except debris flow streams (no data provided or details on analysis)</li> <li>•</li> <li>• Downstream minus upstream temperature differences were all positive (heating in the downstream direction) in 2002, but variable in 2003 (Figure 7)</li> <li>• Multiple regression analysis (Table 4) <ul style="list-style-type: none"> <li>• Shade, elevation, square root of channel gradient, and channel gradient were significant predictors of seasonal maxima (<math>R^2=0.73</math>) and 7-DAD maxima (<math>R^2=0.77</math>)</li> <li>• 7-DAD range was best predicted by shade, square root of channel gradient, and channel gradient (<math>R^2=0.72</math>)</li> <li>• No significant model was found for predicting change in maximum from upstream</li> <li>• Bankfull width, wetted width, depth, and buffer width were not significant predictors in any of the models</li> </ul> </li> <li>• Using all treatment types, mean shade % (i.e. canopy closure %) was found to asymptote at 90 % for buffers 25 meters or greater (this is based on a curve “fitted by eye” (Figure 8)) –however, no observable trend in no-cut buffer width and canopy closure</li> <li>• Shade % required to meet water quality criteria (either AA criteria or Core Rearing Standard) was inversely proportional to channel gradient up to gradients of 25 % (the relationship reaches somewhat of an asymptote beyond 25 to 30 % channel gradient; Figure 9)</li> </ul>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	The study quality relative to the SR question is low. Flaws in the study design as described below limit the statistical power to allow strong reliance upon the results.
Potential sources of bias or error	<ul style="list-style-type: none"> <li>• Use of sites with varying time since treatment management was employed. Even if constrained to a range of 10 years, this introduces uncertainty to the results and potentially low bias for temperature response in clearcuts.</li> </ul>

<b>Publication</b>	(Veldhuisen and Couvelier, 2006)
	<ul style="list-style-type: none"> <li>• Direct comparison of temperature metrics from downstream sensors only (as in Table 3) does not control for factors influencing stream temperature upstream of treatment unit.</li> <li>• The effects of hydroclimatic conditions by year were not assessed, likely because of the study design changing every year, so it is impossible to know what effect lower flows and warmer summers had on the temperature responses.</li> </ul>
Effects modifiers <sup>5</sup>	<p>Stream temperature modifiers assessed in analyses:</p> <p>Shade</p> <p>Elevation</p> <p>Channel gradient</p> <p>Bankfull width</p> <p>Wetted width</p> <p>Depth</p> <p>Buffer width</p> <p>Aspect</p> <p>Other modifiers documented but not assessed in analysis:</p> <p>Age of treatment</p> <p>Upstream management</p> <p>Others:</p> <p>Sensor placement relative to groundwater inflows, springs, or tributary junctions</p> <p>Buffer age</p> <p>Buffer species composition and density</p> <p>Discharge</p> <p>Flow continuity</p> <p>Climate/Air temperature</p>
Notes <sup>6</sup>	While this study does not provide robust and defined results that warrants basing management decisions on, it does highlight the variability in stream temperature response encountered in very small headwater streams.
Method references <sup>7</sup>	

<b>Publication</b>	A. (Wilk et al., 2010)
Study dates and study duration (# of years, dates within a year)	2003-2006, data collected in 2003, 2005, 2006
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Western Washington – Willapa State Province in the Coast Ranges Regional Province
Ecosystem type; plant association group; type of forest	Managed previously logged and naturally regenerated second-growth coniferous forests of mostly western hemlock ( <i>Tsuga heterophylla</i> ), Douglas-fir ( <i>Pseudotsuga menziesii</i> ) and western redcedar ( <i>Thuja plicata</i> ), with vine maple ( <i>Acer circinatum</i> ) in the midstory. Some sites had dense patches of salal ( <i>Gaultheria shallon</i> ) in upland ground cover. Devil's club ( <i>Oplopanax horridus</i> ), salmonberry ( <i>Rubus spectabilis</i> ), western sword fern ( <i>Polystichum munitum</i> ) and redwood sorrel ( <i>Oxalis oregana</i> ) characterized streamside vegetation. Stand ages at the time of logging were 61–108 years.
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	1 <sup>st</sup> and 2 <sup>nd</sup> order streams Catchment size of 1.2 – 8.1 ha Bankfull < 3 m
Research question(s), hypotheses, objectives	“Understanding of alternative buffer designs in the maintenance of streamside small mammal communities by comparing the short-term treatment response of habitat, abundance and composition to measures from prelogging and to measures from uncut reference sites”
Study design <sup>1</sup>	<ul style="list-style-type: none"> <li>• Reaches 80-480 m long</li> <li>• 1 year pretreatment and 2 years post-treatment</li> <li>• Replicated with controls</li> <li>• Vegetated forest stand data collected in four 3x3m quadrats in each of two 10x10 m plots on each side of stream 2-12 m from bank. Data collected include: basal area, QMD, and canopy with hemispherical photos 1.2 m above ground with fisheye converter and 20% mask of sky.</li> </ul>
Pretreatment data (yes/no), # of years of pretreatment data	Yes = 1 year

<b>Publication</b>	A. (Wilk et al., 2010)
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<p>There were two experimental treatments of relevancy: (1) clearcuts with continuous buffer strips from a few to 20m each stream side (n = 7; one or two per cutblock), and (2) clearcuts with small patch (&lt;0.6 ha in size) buffers left to protect sensitive streamside terrain (n = 3; in two of the cutblocks).</p> <p>Six unmanaged controls, one in each cutblock</p>
Replications (if applicable)	Replicates of each method: 6 control, 7 strip buffer, 3 patch leave, 3 patch cut, 7 no buffer
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<ul style="list-style-type: none"> <li>• Measure = change in habitat (understory – richness, evenness, diversity; forest – canopy closure, standing live trees, basal area)</li> <li>• Relative importance = describe habitat</li> <li>• Robustness = sampling methods are robust</li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	<ul style="list-style-type: none"> <li>• Patch cut (n=3) and no buffer (n=7) had significantly different habitat than the control for all outcome measures listed above (Table 1) <ul style="list-style-type: none"> <li>• Patch leave (n=3) had significantly different understory richness and forest canopy closure than the control</li> <li>• Canopy closure (%): <ul style="list-style-type: none"> <li>• strip buffer: <math>-8.6 \pm 3.5</math> (p=0.12)</li> <li>• patch leave: <math>-23.4 \pm 8.7</math> (p&gt;0.05)</li> <li>• control: <math>0.2 \pm 1.2</math></li> </ul> </li> <li>• Basal area (m<sup>2</sup>/ha): <ul style="list-style-type: none"> <li>• Strip buffer: <math>-19 \pm 4</math> (p=1)</li> <li>• Patch leave: <math>-17 \pm 4</math> (p=1)</li> <li>• Control: <math>-10 \pm 7</math></li> </ul> </li> </ul> </li> </ul>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	Low sample sizes. Not entirely certain what statistical analysis method was used.
Potential sources of bias or error	Logging altered stream locations in some cases.
Effects modifiers <sup>5</sup>	Did not test modifiers besides width of riparian reserve, riparian cover, and windthrow
Notes <sup>6</sup>	No direct relationship to shade or temperature, more about plant community composition.

<b>Publication</b>	A. (Wilk et al., 2010)
	Focus of paper was on small mammals.
Method references <sup>7</sup>	

<b>Publication</b>	B. (Wilk et al., 2010)
Study dates and study duration (# of years, dates within a year)	2003 through 2006, 4 years
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Willapa State Province, western Washington State, USA
Ecosystem type; plant association group; type of forest	Northern edge of Coast Ranges Regional Province Naturally regenerated, second-growth coniferous forest (primarily <i>Tsuga heterophylla</i> , <i>Pseudotsuga menziesii</i> , and <i>Thuja plicata</i> )
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	Catchment area: 1.2 to 8.1 hectares Reach lengths (source to confluence): 80 to 480 meters Bankful width: generally < 3 meters  Mostly perennial, with one having a “dry, trickle bed”
Research question(s), hypotheses, objectives	<b>Objective:</b> “...provide a better understanding of alternative buffer designs in the maintenance of streamside small mammal communities by comparing short-term treatment response of habitat, abundance, and composition to measures from prelogging and uncut reference sites.”
Study design <sup>1</sup>	Replicated sampling, replicated control, sampling before and after treatment
Pretreatment data (yes/no), # of years of pretreatment data	Yes, 1 year
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	#1: Clearcut, no buffer #2: Clearcut, with few to 20 meter buffer strip on both sides of stream #3: Clearcut, with small (<0.6 ha) patch buffers at sensitive streamside terrain

<b>Publication</b>	B. (Wilk et al., 2010)
	#4: “Unmanaged” control
Replications (if applicable)	<p>Replication occurred primarily via 6 different study blocks (separated by ~10-80 kilometers)</p> <p>Within block replication minimal</p> <p>Specifics by treatment:  #1 and #2: n=7 (1 or two per cut block)  #3a: n=3 (2 blocks total?)  #3b: n=3 (2 blocks total?)  #4: 1 in each block (6 blocks total)</p>
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<p>Forest stand:  canopy closure % (measured by hemispherical camera) - relevant, robust</p> <p>standing live trees (plot count)- indirectly relevant, robust</p> <p>Forest stand basal area (Spiegel Relaskop)- indirectly relevant, robust</p>
Sample sizes and results with estimates of variation <sup>3</sup>	<p><b><u>#1- Clearcut, no buffer (n=7)</u></b>  canopy closure*: -69.1 +/- 2.6 % (* = significant relative to change in control, alpha=?)  standing live trees*: -518 +/- 115 trees ha<sup>-1</sup>  basal area*: -54 +/- 6 m<sup>2</sup> ha<sup>-1</sup></p> <p><b><u>#2- Clearcut, with buffer strips (n=7)</u></b>  canopy closure: -8.6 +/- 3.5 %  standing live trees: -152 +/- 44 trees ha<sup>-1</sup>  basal area: -19 +/- 4 m<sup>2</sup> ha<sup>-1</sup></p>

<b>Publication</b>	B. (Wilk et al., 2010)
	<p><b><u>#3a- Patch leave (n=3)</u></b>  canopy closure*: -23.4 +/- 8.7 %  standing live trees: -120 +/- 51 trees ha<sup>-1</sup>  basal area: -17 +/- 4 m<sup>2</sup> ha<sup>-1</sup></p> <p><b><u>#3b- Patch cut (n=3)</u></b>  canopy closure*: -67.2 +/- 3.9 %  standing live trees*: -273 +/- 41 trees ha<sup>-1</sup>  basal area*: -38 +/- 4 m<sup>2</sup> ha<sup>-1</sup></p> <p><b><u>#4- Control (n=6)</u></b>  canopy closure: -0.2 +/- 1.2 %  standing live trees: -109 +/- 87 trees ha<sup>-1</sup>  basal area: -10 +/- 7 m<sup>2</sup> ha<sup>-1</sup></p>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	
Potential sources of bias or error	Typical error associated with these types of measurements
Effects modifiers <sup>5</sup>	
Notes <sup>6</sup>	Although this study was conducted within the geographical range of this SR and deals with riparian management, its usefulness is primarily linked to the possibility of correlating changes in riparian basal area with changes in canopy closure for this forest type. If the results were paired with stream temperature data, this study may have provided more useful information for addressing the SR questions.
Method references <sup>7</sup>	

<b>Publication</b>	(Zwieniecki and Newton, 1999)
Study dates and study duration (# of years, dates within a year)	July and August 1995

<b>Publication</b>	(Zwieniecki and Newton, 1999)
Study location (watersheds, region/state, country), settings where riparian buffers were applied	Western and northwestern Oregon
Ecosystem type; plant association group; type of forest	Low elevation sites
Stream size (avg. annual flow, contributing area, HUC, avg. wetted width, etc.)	Discharge ranged from 0.0004-0.022 m <sup>3</sup> /km <sup>2</sup> s (0.006 m <sup>3</sup> /km <sup>2</sup> s average) Depth ranged from 0.04-0.47 m (0.20 m average) Width ranged from 0.7-7.0 m (3.4 m average)
Research question(s), hypotheses, objectives	Hypothesis: “each stream has its own temperature signature reflecting its specific environment and flow pattern” Objective: “evaluates the direct effect on summer maximum stream temperature of various timber harvest units along forested streams with tree buffers of varying widths and arrangements; it also examines trends in the return to the temperature signature”
Study design <sup>1</sup>	<ul style="list-style-type: none"> <li>• 14 forested streams</li> <li>• Temperature data collected at four or more continuous recording temperature monitors installed: immediately upstream and downstream of harvest unit boundary and 150 and 300 m downstream.</li> <li>• Stream depth, wetted width, gradient and cover were collected every 30 m within the harvest unit and within 300 m upstream and downstream of the harvest unit.</li> </ul>
Pretreatment data (yes/no), # of years of pretreatment data	None
Details on management action(s) (e.g., sizes and types of buffers; clearcut or thin on both or single sides of streams)	<ul style="list-style-type: none"> <li>• Clearcutting on one or two sides of the streams while leaving tree buffers of varying widths.</li> <li>• Some streams included natural and/or cleared overstory gaps.</li> <li>• Buffer width ranged from 8.6 to 30.5 m.</li> <li>• Harvest according to: Hardwood Conversion Rules, Best Management Practices, or experimental (one-sided (south) buffers of 12 m as part of Hardwood Conversion Rules.</li> </ul>
Replications (if applicable)	3 Geographic Regions, 2 harvest prescriptions, 2 stream sizes resulted in none or one

<b>Publication</b>	(Zwieniecki and Newton, 1999)
	replication
Nature of the outcome measures used, their relative importance and robustness <sup>2</sup>	<p>7-day moving mean maximum stream temperature</p> <ul style="list-style-type: none"> <li>• Importance: authors selected the warmest weather periods to find the highest temperatures that fish would have to tolerate</li> <li>• Robustness: measure is well-recognized and considered strong if the temperature data is collected appropriately</li> </ul> <p>Cover density: measured with a spherical densiometer</p> <ul style="list-style-type: none"> <li>• Importance: considered as a surrogate for shade</li> <li>• Robustness: measurement error is frequently a concern with densitometers, little explanation was given to describe methodology for reducing this potential error</li> </ul>
Sample sizes and results with estimates of variation <sup>3</sup>	<ul style="list-style-type: none"> <li>• Cover was 78% within harvest units and 83% above and below harvest units (n=14), though no significant differences.</li> <li>• Absolute water temperatures were 1.09 °C higher in the harvest unit (p=0.0005).</li> <li>• Temperature decreased by 0.69 °C in the first 150 m downstream of the harvest unit (p=0.08).</li> <li>• From top to bottom of entire study reach (upstream, within, downstream) temperature rose 0.55 °C (p=0.07).</li> <li>• Streams harvested on one side only appear to have smaller changes in temperature and quicker recovery, though sample size is low and no statistical analysis was conducted (Figure 3).</li> <li>• Hardwood Conversion Units look to have greater increases in temperature and slower recovery than BMP units, also no statistical analysis conducted (Figure 3).</li> </ul>
Notes concerning study quality with evidence or reasoning behind the notes <sup>4</sup>	<p>Conclusions regarding cumulative effects are neither well tested nor represented by the data. There is evidence of temperatures rising and then decreasing substantially downstream, but this does not equate to the term ‘cumulative effects’. Also, the sampling window is short enough that cumulative effects over the season cannot be described.</p> <p>It is not completely clear how the different harvest management practices affected temperature – differences by harvest practice not clearly reported or discussed.</p>

<b>Publication</b>	(Zwieniecki and Newton, 1999)
Potential sources of bias or error	Methods for deploying stream gages is not clearly defined.
Effects modifiers <sup>5</sup>	Direct measures: tree buffer width, density of cover, gradient, wetted width, stream depth  Indirect measures: harvest on one or both sides of stream
Notes <sup>6</sup>	
Method references <sup>7</sup>	

**Completed Table A.6.3 Summary of information from each study that indicates its quality and relevance to the review question. An X indicates the study incorporates this characteristic.**

ID*	Study	Quality							Confidence score*	Relevance			
		Duration (years)	Pre-treatment <sup>1</sup> (yrs)	Study design <sup>2</sup>	N <sub>replicate</sub> <sup>3</sup>	N <sub>control</sub> <sup>4</sup>	N <sub>sites</sub> <sup>5</sup>	Statistically robust <sup>6</sup>		Geography <sup>7</sup>	Mountains <sup>8</sup>	Stream size <sup>9</sup>	Question/Objective <sup>10</sup>
A	(Allen and Dent, 2001)	1	0	L	1-13	5	19	H	7	H	X	H	H
B	(Brazier and Brown, 1973)	1	0	L	0	11	11	M	5	H	X	H	H
C	(Brosofske et al., 1997)	1-2	1 yr., 5 sites	M	0	5	14	M	6.5	X	X	H	L
D	(Danehy et al., 2007)	1	0	L	6	6	7	M	7	X	X	H	L
E	(Dent, 2001)	2	1	M/L	0-6 /site type	18	18	L	6.5	H	H	H	H
F <sub>1</sub>	(Dent and Walsh, 1997)	1	0	M/L	2-3/site type	11	11	L-M	6	H	H	M	H
G <sub>2</sub>	(Gomi et al., 2006)	5	1-2	H/M	0-1	3	3	H	9.5	H	X	H	H
H <sub>3</sub>	(Groom et al., 2011a)	6	2	H	14-17	18 (PF), 15 (SF)	18 (PF), 15 (SF)	H	12	H	X	H	H

I <sub>3</sub>	(Groom et al., 2011b)	4 out of 6 year window	2 (31 sites)	H	14-17	18 (PF), 15 (SF)	18 (PF), 15 (SF)	H	12	H	X	H	H
J <sub>3</sub>	(Groom et al., 2013)	Up to 6 years	Up to 4 years	H	14-17	18 (PF), 15 (SF)	18 (PF), 15 (SF)	H	12	H	X	H	H
K	(Hunter, 2010)	4	2-3	L	0	7	7	L	6	H	X	H	H
L <sub>4</sub>	(Jackson et al., 2007)	4	1	M	0	4	4	L	7	H	X	H	L
M <sub>4</sub>	(Jackson et al., 2001)	2	1	M	0	4	3 buffered 1 non-merchantable buffer	L	6	H	X	H	H
N <sub>5</sub>	(Janisch et al., 2012)	4 to 5 per catchment cluster	1-2	H	4-9	CTD/Temp 8/6	CTD/Temp 10/6 continuous buffers 5/5 patch buffers	H	12	H	X	H	H
O <sub>2</sub>	(Kiffney et al., 2003)	1	0	M	2	3	6	L	6	H	X	H	H
P	(Martin, 2004)	2	1-2	M	2	3	3	M	8	M	X	H	H
Q	(Morman, 1993)	3	1	L	0	29	29	L	6	H	X	L	H
R	(Newton and Cole, 2013a)	8	2	H	2	3	3	H	11	H	H	H	H
S <sub>1</sub>	(Newton and Cole, 2013b)	2	0	L	3	4	4	M	7	H	H	H	H
T	(Rashin et al., 1992)	1	0	L	0	9	9	L	4	H	X	H	H

U	(Schuett-Hames et al., 2012)	3 out of 5 yrs	0	L	2-12	14 total, but 1 per treatment location	13 50-foot buffers 3 PIP buffers	L	7.5	H	X	H	H
V	(Steinblums et al., 1984)	1	0	L	0	12	28	M	5	H	H	H	H
W	(Veldhuisen and Couvelier, 2006)	3	0	L	0	5 for 2002 13 for 2003	2002/2003 Buffered=7 / 11	L	6	H	H	H	H
X <sub>5</sub>	(Wilk et al., 2010)	2	1	M	2-6	6	10	H	9.5	H	X	H	L
Y <sub>1</sub>	(Zwieniecki and Newton, 1999)	1	0	L	2-5	14	14	M	6.5	H	H	H/L	H

\*Relates publications to ID for graphing purposes. Publications with the same subscript are from the same study (see Table 2).

<sup>1</sup>Data collected before treatment with the number of years of pre-treatment data in parentheses (X=yes, blank=no)

<sup>2</sup>H=high=Replicated sampling, replicated controls, sampling before and after treatment; M=medium=unreplicated, controlled, sampling before and after treatment; L=low=unreplicated, uncontrolled, sampling before and after treatment or unreplicated, controlled, sampling after treatment (modified from (Fazey and Salisbury, 2002)).If mixture (e.g., some sites with and some sites without replicates), give mixed rating (e.g., L/M).

<sup>3</sup>Number of treatment replicates; add succinct description (e.g., “9 sites, 3 yrs. Post-treatment, treatment X”), knowing that greater detail is captured in Table B2.

<sup>4</sup>Number of control replicates; add succinct description (e.g., “9 sites, 3 yrs. Post-treatment, treatment X”), knowing that greater detail is captured in Table B2.

<sup>5</sup>Number of samples; add succinct description (e.g., “9 sites, 3 yrs. Post-treatment, treatment X”), knowing that greater detail is captured in Table B2.

<sup>6</sup>H=high= stream temperature autocorrelation dealt with, data not combined across sites without accounting for site differences; M=moderate= contains some features of High as applicable; L=low=statistical tests used (or not) but ignore site differences or autocorrelation

\*sum of quality points for duration, study design, number of replicates, and statistically robust columns. Points are H=3, M=2, L=1; for duration, points are 1, 2,3 for 1, 2, and ≥3 seasons, respectively; for number of replicates, points are 1, 2, 3 for 0-1, 2-3, and ≥4 replicates, respectively. If a rating is between two, then the points are between these two (e.g., L/M, or duration=1 or 2 years, depending on the site, then the points would be 1.5).

<sup>7</sup>H=high= west of crest of Cascades in OR, WA, BC plus the Siskiyous (i.e., sites most similar to those in western Oregon);  
L=low=Coast Range of N. CA, Vancouver Island, NW BC, SE Alaska (i.e., sites somewhat similar to those in western Oregon).

<sup>8</sup>In mountainous terrain (X=yes, blank=no)

<sup>9</sup>H=high=small or medium streams as defined in either of (Groom et al., 2011b; ODF, 1994) (i.e., with contributing areas < 7500 ac.(30 km<sup>2</sup>), or average annual flow < 10 cfs, or wetted width <3.7 m, or bankfull width < 7.9 m); L= low = “near” medium size stream (i.e., contributing areas 7500 - 11250 ac. (30-45 km<sup>2</sup>), or 10 - 15 cfs average annual flow, or 3.7 - 4.0 m wetted width, or 7.9 - 8.7 m bankfull width)

<sup>10</sup>H=high=study objectives or questions directly relate to review question; L=low= study has relevant data even though study objectives or questions are not directly related to review question.

**Completed Table A.6.4 Relevance of each study to each rule alternative as listed in Table A.5.1.**

High relevance (H) indicates study directly addressed a particular rule alternative; low relevance (L) indicates study indirectly addressed a rule alternative; blank indicates did not address rule alternative.

Study	Current FPA <sup>1</sup>	State Forests Standards <sup>1</sup>	Derived variable retention	Large tree variable retention	Minimize gaps	Basal area retention by aspect	Field-based shade standard	Shade approach from WA DNR method	Shrub shade	Hardwood sites	Hardwood shade	Derived no-cut buffer	No-cut aspect buffers	Oregon Plan	Plan for alternate practice <sup>2</sup>	One-sided buffer
(Allen and Dent, 2001)		L				L					L	H	L		H	
(Brazier and Brown, 1973)	L	L	L	L			L	L				H		L	L	
(Brosofske et al., 1997)												H			L	
(Danehy et al., 2007)												H				
(Dent, 2001)	H									L	L	H			H	
(Dent and Walsh, 1997)	H									L					H	H
(Gomi et al., 2006)	L	L	L									H	L	L	L	
(Groom et al., 2011a)	H	H										L				L
(Groom et al., 2011b)	H	H				L	L				L					
(Groom et al., 2013)	H	H														
(Hunter, 2010)	L	L	L	L	L		L	L		L	L	L	L	L	H	L
(Jackson et al., 2007)	L	L					L	L	L			H	L	L	H	
(Jackson et al., 2001)	L	L										H			H	
(Janisch et al., 2012)	L	L				L	L	L				H	L	L	H	
(Kiffney et al., 2003)	L	L					L	L				H	L	L		
(Martin, 2004)			H									L				
(Morman, 1993)	L		H						L	L				L		L
(Newton and Cole, 2013a)	H								L					L	L	
(Newton and Cole, 2013b)			L		L	L			H	L	L					
(Rashin et al., 1992)	L	L	L	L	L	L	L	L		L	L	H	L	L	L	L
(Schuett-Hames et al., 2012)	L	L	L			L	L	L	L	L	L	H	L	L	H	

(Steinblums et al., 1984)	L											H				L
(Veldhuisen and Couvelier, 2006)		L	L				L	L				H			L	
(Wilk et al., 2010)												H			H	
(Zwieniecki and Newton, 1999)	H									L					H	H
Total # studies (pubs) High relevance**	4(7)	1(3)	2	0	0	0	0	0	1	0	0	12(15)	0	0	7(10)	1(2)

<sup>1</sup> Standards are summarized in (Groom et al., 2011b).

<sup>2</sup> Any other type of treatment that may have been studied.

<sup>3</sup> A study is considered directly relevant (H) if it provides quantitative data that addresses whether or not a particular design or prescription of a rule alternative is effective at preventing warming or maintaining shade. A study is considered indirectly relevant (L) if it provides information that can give some insight to effectiveness of a particular rule alternative.

<sup>4</sup> Effective at preventing stream from warming or maintaining shade: ++= prevented warming or maintained shade; += reduced warming or had a smaller decrease in shade relative to another treatment (indicated with ') or control (indicated with \*), 0= no change; I= inconclusive; - =resulted in maximal warming or largest decrease in shade compared with other treatments. Note that effectiveness is only categorized where a study is highly relevant to a rule alternative.

\*\*Sum of all studies that are highly relevant for each rule alternative; parentheses indicates the total number of publications relevant to a particular alternative if different than the number of studies. See Table 1 for clarification of relationship between studies and publications.

## Appendix C. Data for Geographic Regions analysis.

**Table C1. Data to compare effectiveness of different buffer prescriptions between ODF Geographic Regions for each study.**

These data are illustrated in Figures 2 and 3 of the report.

<u>Presc.</u> <sup>†</sup>	<u>Publication(s)</u> <sup>α</sup>	<u>Geog. Regions (# sites w/ prescr.)</u> <sup>*</sup>	<u>Conf. score</u>	<u>Outcome data comparison between Geog. Regions</u> <sup>††</sup>			
FPA	Dent, 2001	CR (1), I (6)	6.5		CR	I	
				Cover	+4	+2, -4, -6, -8, -16, -18	
FPA	Dent and Walsh, 1997; Zwieniecki and Newton, 1999	CR (3), I (1)	6, 6.5		CR	I	
				Cover	+8, -1, -18	+9	
				Temp.	0.4, 1.8, 1.6	1.6	
FPA	Groom <i>et. al</i> , 2011a, b, 2013	CR (16), I (2)	12	NA			
FPA	Newton and Cole, 2013a	CR (1), I (2)	11		CR	I	
				Temp.	1.3	-0.1, 0.6	
FMP	Groom <i>et. al</i> , 2011a, b, 2013	CR (14), I (1)	12	NA			
Variable Retention	Morman, 1993	CR (9), I (8) <sup>αα</sup>	6		width	CR	I
				shade	43'	-32	-9
				shade	48'	-20	-22
Shrub shade	Newton and Cole, 2013b	CR (1), I (1), WC (1)	7		CR	I	WC
				Temp.	-0.3	1.2	1.2
No-cut	Allen and Dent, 2001	CR (14)	7	NA			
No-cut	Brazier & Brown, 1973	CR (7), I (4) <sup>αα</sup>	5		Width	CR	I
				Cover	10'	-24	-61
					50'	0	-6, -3
				Temp.	10'	9	7.5
					50'	3	2, 6
No-cut	Danehy <i>et. al</i> , 2007	CR (7)	7	NA			
No-cut	Dent, 2001	I (1)	6.5	NA			
No-cut	Steinblums <i>et. al</i> , 1984	I (18), WC (22)	5	NA			
HWC	Allen and Dent, 2001	CR (2)	7	NA			
HWC	Dent, 2001	CR (3)	6.5	NA			
HWC	Dent and Walsh, 1997;	CR (2), I (2)	6, 6.5		CR	I	

<b>Presc.<sup>†</sup></b>	<b>Publication(s)<sup>α</sup></b>	<b>Geog. Regions (# sites w/ prescr.)*</b>	<b>Conf. score</b>	<b>Outcome data comparison between Geog. Regions<sup>††</sup></b>		
	Zwieniecki and Newton, 1999			Cover	-10, -20	+6, -10
				Temp.	3.2, 1.7	1.7, 0.4
South-sided	Dent and Walsh, 1997; Zwieniecki and Newton, 1999	CR (2), I (1)	6, 6.5		CR	I
				Cover	0, -5	-7
				Temp.	0, 1.4	0.1

<sup>†</sup>Type of buffer prescription, related as closely as possible to the rule alternatives. HWC (hardwood conversions) is considered under the “Plan for alternate practice” rule alternative.

<sup>α</sup> Note that many publications test several different prescriptions.

\*Geographic Regions included in this analysis: CR = Coast Range; I = Interior; WC = West Cascade.

<sup>††</sup> All data are difference between post-harvest and control; cover/shade in %, temperature in °C. Note that data are compared only within a study since methods, and therefore data, might differ between studies. “NA” is for data that are not readily extractable from the publication [Groom *et al.* [2011a, b, 2013], Steinblums *et al.* [1984]], or data are only from one Geographic Region.

<sup>αα</sup> Brazier and Brown (1973), and Morman (1993) each had internally comparable data for only a few buffer widths.

## **Appendix D. Draft report, with additions**

This appendix includes the Draft Report and significant additions (i.e., Executive Summary, and Geographic ranges and physical settings) to this draft after it was completed. These documents were sent to stakeholders and technical experts in July 2013 for their review and comment (see Appendix E) since we wanted to both be more inclusive in the process of developing this report, and because their input strengthened the review. These documents are in this appendix for transparency and to provide context for their comments.

## **D.1 Draft Report**

### ***1. Draft Introduction***

#### ***1.1 Background***

Many Oregon streams support several cold-water fisheries (e.g. salmon, steelhead, cutthroat) which are important to the region's economy, culture, and recreational activities. These fish are thermally adapted to specific water temperature regimes for various life stages such as egg and smolt survival, spawning, and adult migration (Richter and Kolmes, 2005). These regimes are affected by several natural processes including direct exposure to sunlight, the transfer of heat from water to the air or stream bed, evaporation, water exchange with groundwater or the hyporheic zone, and others (Brown, 1969; f Johnson, 2004). Of these factors, direct exposure to sunlight is a major contributor to maximum daily summer stream temperatures, and this exposure may increase following timber harvest (Brown and Krygier, 1970; Johnson, 2004; Sinokrot and Stefan, 1993). Therefore, maintaining riparian shade may serve as an effective tool for minimizing the increases in stream temperature during the summer months when maximum stream temperatures are observed (Johnson, 2004).

Oregon has enacted timber harvest regulations to maintain shade on streams following timber harvest (Oregon Department of Forestry, 2010). Timber harvest operations are considered in compliance with Oregon Department of Environmental Quality (DEQ) water quality standards (Oregon Department of Environmental Quality (ODEQ), 2004) if harvest operations comply with the Forest Practices Act (FPA; ORS 527.770). The Oregon Department of Forestry (ODF) must establish best management practices and rules that will meet state water quality standards and periodically conduct studies to determine if the FPA effectively meets state water quality standards (ORS 527.765, 527.710).

ODF initiated its Riparian and Stream Function (RipStream) monitoring project in 2002 to assess the effectiveness of FPA and State Forests standards at complying with DEQ water quality standards for temperature. One of the temperature criteria examined was the Protecting Cold Water (PCW) criterion, which is designed to prevent warming of streams that are currently cold enough to protect fish. This criterion prohibits human activities such as timber harvest from increasing stream temperatures by more than 0.3 °C at the point of maximum impact where: a)

salmon, steelhead or bull trout are present; b) streams are designated as critical habitat for salmonids; or c) streams are necessary to provide cold water to a) (OAR 340-041-0028 (11)). An analysis of the pre and post-harvest data indicated that the PCW criterion was likely not being met at all study sites with FPA buffers (i.e., these sites frequently exhibited temperature increases greater than 0.3 °C; (Groom et al., 2011b)). This finding of degradation has initiated an FPA riparian rule analysis process (ORS 527.714(5)(a)). The geographic scope of the findings of degradation are based on (Groom et al., 2011a, 2011b), which studied streams in the Coast Range and Interior Geographic Regions of Oregon (as defined in OAR 629-635-0220). While the exact geographic extent of the rule analysis is yet to be determined, it will be limited to western Oregon. This limitation is due to the vegetation, climate and hydrologic characteristics of eastern Oregon being significantly different enough from those included in the RipStream study to preclude extending a rule to eastern Oregon. As part of this rule analysis process, stakeholders contributed 16 alternative methods of riparian management as options for meeting the PCW standard during future near-stream harvest operations. The Oregon Board of Forestry approved consideration of these 16 alternatives at their July 2012 meeting.

ODF is conducting this systematic review (SR) to fulfill a requirement of the rule analysis process: proposed rules must reflect available scientific information (ORS 527.714 (5)(c)). The SR will also serve to inform the decision on the geographic extent of the rule analysis process relative to the RipStream findings on FPA sufficiency. Therefore, this SR will, through evaluating a focused question, directly assist in evaluating the 16 alternative scenarios for riparian management and help inform the ODF rule analysis process. However, this review will not recommend which alternative is the best to choose, nor explicitly define a particular rule prescription.

## ***1.2 Objective of the Review***

This systematic review is designed to provide scientific guidance, per Oregon Revised Statutes 527.714 (5)(c), to the Oregon Board of Forestry in addressing the following rule analysis objective developed by the Board at their April 2012 meeting:

Establish riparian protection measures for small and medium fish-bearing streams that maintain and promote shade conditions that insure, to the maximum extent practicable, the achievement of the Protecting Cold Water criterion.

Small streams are defined as having average annual flows  $\leq 57$  L/s (2 cfs), and medium streams are defined as having flows  $> 57$  L/s (2 cfs) and  $\leq 283$  L/s (10 cfs; Oregon Department of Forestry, 2010). Fish-bearing streams are those for which anadromous, game, or threatened and endangered fish presence has been observed or modeled. Specifically, this review is designed to provide insight on the efficacy of the 16 rule alternatives that were approved by the Board at their July 2012 meeting (Table A.5).

## ***2. Draft Methods***

This section summarizes the protocol for conducting the systematic review (for details of the methods, refer to Appendix A). Note that the tables to be completed by the reviewers are listed in Section A.6, whereas their associated completed forms are in Appendix B. The protocol was approved by the Oregon Board of Forestry at their meeting on 6 March, 2013, and was modified slightly during the review process.

### ***2.1 Purpose of protocol for systematic review***

Protocols provide a road map for how to conduct a systematic review of scientific literature relevant to a narrowly-defined question (Centre for Evidence-based Conservation, 2010). A systematic review seeks to answer this question with evidence, as opposed to the authors' interpretation of such evidence, from existing studies that are rigorously screened for quality and relevance to this question. The structured process provides for rigor and transparency concerning how studies are searched for, which ones are included in the review, and how they are analyzed. This process also allows for a review to be either updated in the future, or completed by another party.

### ***2.2 Review partners***

Numerous partners strengthened the quality of this systematic review. ODF staff composed an initial draft of the protocol, then obtained input on it from a group of stakeholders and the RipStream External Review Team (RSERT). These groups included university, federal,

forest industry, and state scientists; staff from the Oregon Departments of Forestry, Environmental Quality, and Fish & Wildlife; and nongovernmental organizations including Pacific Rivers Council. Similarly, a reference librarian from the Oregon State Library assisted in refining the search strategy. Finally, ODF coordinated the work of these partners, plus that of the external reviewers. All partners had the opportunity to provide input on:

- The protocol and question for this review;
- A draft list of publications to consider for inclusion in the review to assess if any studies were not found;
- A draft list of included publications to assess whether or not the inclusion criteria were appropriately applied;
- A draft of the completed SR report.

To minimize bias in the review, ODF hired external scientists to conduct the review. These reviewers first cross-checked their work by reviewing a subset of studies (including assessing their study relevance, quality, and extracting the data). Each reviewer then independently reviewed half the remaining studies included in the review. The protocol was modified during the review process, with alterations documented in Appendix A where the reviewers, in coordination with ODF, found ways to improve the protocol. After analyzing the articles, the reviewers collaboratively wrote this report synthesizing their analyses.

### ***2.3 Review questions***

#### **Primary review question**

Systematic reviews are designed to assess a body of literature through the lens of a focused question regarding the efficacy of active treatments, rather than a general topic of concern to policy or practice. The question should be value-free to the extent possible, answerable in scientific terms, and specify the subject, treatment, comparator, and outcome(s) of interest. The question is also important since it is used to generate terms used in the literature search and to determine relevance criteria.

The elements of this review's question are based on the rule analysis objective and the finding of degradation, and were developed by several partners in stages. ODF staff (T. Frueh, J. Groom, and M. Allen) developed a draft review question. The question was refined in

consultation with representative stakeholders and RSERT to ensure the question's importance and appropriateness of scope for this review. The question was then further refined with ODF input. The review question is:

**For small and medium streams in the western Pacific Northwest, in or adjacent to forest harvest operations, what are the effects of near-stream forest management on stream temperature and/or riparian shade?**

Secondary question

This review evaluated differences between studies that might explain variations among study outcomes. These differences may be due to effects modifiers (see Section A.3.3 for more information on these modifiers), and this secondary question explicitly addresses the causes of these differences. To the extent that relevant information is available in reviewed studies, this secondary question was addressed:

**For small and medium streams in the western Pacific Northwest, in or adjacent to forest harvest operations, how do effects modifiers (e.g., discharge, substrate characteristics, length of buffers, stream aspect), in combination with near-stream forest management, change stream temperatures or riparian shade?**

### **2.3 Search strategy**

An important aspect of systematic review is the use of a search strategy that specifies, *a priori*, how a comprehensive and unbiased sample of the literature will be searched. We decided to search as wide as possible, then use rigorous inclusion criteria to determine which studies to include. All publications found in each searched source were saved in a database, except for internet searches from which the first 100 results were reviewed for relevant publications (this restriction follows CEBC guidance). Results with indeterminate information (e.g., incomplete citation) or duplicates were discarded. For every search, the following information is documented (see Data Supplement 1, SearchScoping.xls):

- Date when search was conducted
- Database, search engine, website, library, or professional contact that was queried
- Exact search strings used

### **2.4 Study inclusion criteria**

Study inclusion criteria are predefined to ensure an objective selection of the relevant literature. For this review, the studies must directly inform the primary review question in the

context of the rule alternatives and rule objective. Only primary studies (i.e. studies with original data, not reviews, modeling, or meta-analyses) were included since ODF wants to base the rule analysis on evidence, not authors' interpretation of the evidence. While peer-reviewed articles are the gold standard in science, we decided to include "gray literature" (i.e., articles that might have less rigor in either peer-review or research methods and analysis, e.g., government reports, graduate theses) and manuscripts in review because some of these studies are most relevant to the review question. It is a common requirement that agencies (e.g., ODF, Washington Dept. of Natural Resources) assess the effectiveness of their respective rules via studies, thus this gray literature is likely to be highly relevant to the primary review question. In addition, only studies that measure the effects of recent forest harvests, with near-stream areas managed for protecting water (e.g., similar to OAR 629-635-0100), on stream temperature or riparian shade were included since these elements are essential to analyze the riparian rule objective that provides the impetus for conducting this study. Restricting studies to those of "recent" harvest is warranted due to the decline, with time, of adverse impacts of harvest on stream temperature and riparian shade (Hale, 2007; Johnson and Jones, 2000). The final inclusion criteria are:

- Studies must have proper controls with which to measure the effects of buffer treatments;
- Studies must have been conducted in sites with similar stream sizes and forest types as ODF's water classification of small and medium streams (OAR 629-635- 0310); and,
- Studies must have been located in similar forests as those of western Oregon.

Inclusion criteria are further detailed in Table A.6.1.

With these criteria in mind, inclusion was determined initially on viewing the titles of articles. When titles provided insufficient information to ascertain consistency with inclusion criteria, the ODF review coordinator read abstracts to determine inclusion. Where there was still insufficient information to make a decision, an article's inclusion was determined by reading the full text. Studies that meet all inclusion criteria were reviewed by the external reviewers. For transparency, the fate (i.e., inclusion or exclusion), and basis for this decision, of each publication found in the search are documented in Data Supplement 1.

## ***2.5 Potential effects modifiers***

Although studies may have very similar methods, they may show differences in the measured outcomes. These differences may be due to circumstances ("effects modifiers") that

alter the outcomes. For example, two studies may have identical buffer widths, yet if they have different buffer lengths, they might exhibit different changes in stream temperatures. Thus, these effects modifiers are important to consider when synthesizing the information extracted from studies. The role effects modifiers played in study outcomes is assessed using Table A.6.2 and are discussed in the narrative synthesis (Section 3).

## **2.6 Data extraction strategy**

When conducting a systematic review, it is important to extract both information about studies and their respective primary data. This information focuses the review on evidence instead of authors' interpretation of the evidence. The data extraction tables allow for objective and transparent extraction of this data. In addition, these tables help to highlight gaps in our understanding. For this study, these data were compiled using Table A.6.2 for each study. This table was developed by modifying those of (Bowler et al., 2008; Burnett et al., 2008), testing data extraction with several studies, and with input from RSERT and stakeholders. Reviewers also assessed various components (e.g., bias, effects modifiers) that provide a more complete understanding of the context, relevance and relative strength of studies (Table A.6.2).

## **2.7 Study quality assessment and relevance**

When synthesizing data from the studies, it is important to consider both the quality of each study and its relevance to the review question. For example, a study might have directly addressed the review question, yet was poorly conducted so as to provide little confidence in the study's results. Conversely, a study may have been conducted very well, yet has only weak relevance to the review question.

External reviewers completed tables that enable quick, objective comparisons of studies. Table A.6.3 addresses the quality of studies by determining e.g., the rigor of their controls, and number of replicates. A summary metric, Confidence Score, combines the various aspects that make for a high quality study. This metric is designed to help assess the quality of the information when looking at the effectiveness of a particular buffer type (e.g., Figures 1-12). This table also determines study relevance to the review question by determining how close studies are geographically and in stream size to those of (Groom et al., 2011a). Table A.6.4 determines

whether studies directly or indirectly addressed a rule alternative, and a relative assessment of the effectiveness of buffer treatments at protecting cold water or shade. Additional reviewer notes that further illuminate study quality and reference (e.g., robustness of study measures, sources of bias, consideration of effects modifiers) are listed using Table A.6.2.

## **2.8 Data synthesis**

To make sense of the information extracted and analyzed from the studies, a narrative synthesizes the information collected in Completed Tables A.6.2-A.6.4 (Appendix B). This synthesis assesses the differences and commonalities between riparian management scenarios used in studies and their respective outcomes. For each rule alternative, the synthesis discusses:

- The number of studies that directly or indirectly address the alternative;
- The evidence from a suite of studies regarding the effectiveness of the alternative, including:
  - range of variation in metrics defining each alternative (e.g., buffer width, basal area retention)
  - range of variation in outcomes measured
  - degree of effectiveness at protecting cold water or riparian shade
- The role of effects modifiers in the stream temperature and riparian shade outcomes that were measured; and
- Significant gaps in our understanding.

The synthesis also examines the magnitude of influence the effects modifiers had on results.

## **3. Draft Results and Synthesis**

### **3.1 Literature search and filter**

In a search of studies relevant for this review, 1456 studies were identified, of which 25 met all criteria for inclusion in the review (see Table 1 and Data Supplement 2, LitSearchFilter.xls). Of studies excluded from the review, approximately 80% were rejected by reading the title, ~10-15% were rejected by reading the abstract, and the remainder required reading a portion of the complete text. When stakeholders and technical experts were asked to

provide input on the results of the literature search and filtering process, zero comments were received.

While we did not conduct an exhaustive process to evaluate the effort required to locate the 25 studies included in this review, we have some information that may be helpful in thinking about conducting a similar review. We only recorded the first type of search (e.g., database, reference) that found a study. We searched databases first, which found 1245 studies. Of these studies, nine were included in the review. Upon re-analysis, all of these studies were located by examining references of included studies or related review papers. In contrast, nine studies were found via only one search method: four unpublished studies were only found by contacting researchers (three studies were under review (Groom, 2013; Newton and Cole, 2013a, 2013b), and five studies were only found by searching agency websites (Dent and Walsh, 1997; Hunter, 2010; Martin, 2004; Morman, 1993; Veldhuisen and Couvelier, 2006).

243 **Draft Table 1. Summary information on publications included in the review.**

ID*	Study	Location (georegion) <sup>†</sup>	Pub. type <sup>††</sup>	Rel.? <sup>a</sup>	Buffer Prescriptions***	Effectiveness data (location of data, method of extraction if applicable)	Measurements																	
							Temp.	Sh.																
A	(Allen and Dent, 2001)	OR (CR, BM)	Gov't.	Y	14 no-cut buffers (20-70 ft.; 6-21 m), 2 riparian conifer restorations (RCR), 2 site-specific (SS) plans	Range in difference in shade (Table B1, excluding large stream and Blue Mtn. data, measured with respect to avg. forested shade ) no-cut (n=14): -38 to -4%; RCR (-28, -6%), SS (-9, 0%)		X																
B	(Brazier and Brown, 1973)	OR (CR, I(?))	Gov't.	Y	11 no-cut buffers (10-60 ft.; 3-18 m)	Range in change in canopy cover (Fig. 5; 10-60' buffers values compared with those at 100'): 0 to -60%  Observed temp. change (Table 1) +0.6 to +5 °C	X	X																
C	(Brososke et al., 1997)	WA (Cascades)	PR	N	14 no-cut buffers (26-141 ft.; 8-43 m)	Range in change in radiation (Fig. 8): 0 to +0.1 kW/m2		X																
D	(Danehy et al., 2007)	OR (CR)	PR	N	7 no-cut buffers (49 ft.;15 m)	Change in temperature (Table 1, measured with respect to mean mature): 0.0 °C  Change in insolation (Table 1, measured with respect to mean mature; MJ/m2/day): uncut (+95 ±89), thinned (+137± 28)	X	X																
E	(Dent, 2001)	OR (BM, CR, EC, I, S, WC)	Gov't.	Y	1 no-cut buffer (70 ft.; 21 m); 3 riparian conifer restorations; 7 standard Forest Practices Act (FPA) prescriptions.	Change in cover (averages for medium (M) and small (S) streams west of Cascade crest, Table 6): No-cut, medium (n=1): -2%; FPA: small (n=3): -9% (range -4 to -16), Med (n=4): -4.5% (range -18 to +4); RCR: small (n=2): -20% (-6, -34); Med. (n=1): -36%		X																
F <sub>1</sub>	(Dent and Walsh, 1997)	OR (CR,I)	Gov't.	Y	4 standard FPA prescriptions; 4 hardwood conversions (HWCs); 3 HWCs limiting openings on south side of streams	From Table 3 <table><tr><td>Rule</td><td>n</td><td>Avg. Change 7-D max., °C (range)</td><td>Avg. change in cover, % (range)</td></tr><tr><td>FPA</td><td>4</td><td>+2.4 (+0.6 to +3.3)</td><td>-0.5 (-18 to +9)</td></tr><tr><td>HWC</td><td>4</td><td>+4.1 (+0.7 to +5.7)</td><td>-8.5 (-20 to +6)</td></tr><tr><td>S. Side</td><td>3</td><td>+0.7 (+0.07 to +2.6)</td><td>-4 (0 to -7)</td></tr></table>	Rule	n	Avg. Change 7-D max., °C (range)	Avg. change in cover, % (range)	FPA	4	+2.4 (+0.6 to +3.3)	-0.5 (-18 to +9)	HWC	4	+4.1 (+0.7 to +5.7)	-8.5 (-20 to +6)	S. Side	3	+0.7 (+0.07 to +2.6)	-4 (0 to -7)	X	X
Rule	n	Avg. Change 7-D max., °C (range)	Avg. change in cover, % (range)																					
FPA	4	+2.4 (+0.6 to +3.3)	-0.5 (-18 to +9)																					
HWC	4	+4.1 (+0.7 to +5.7)	-8.5 (-20 to +6)																					
S. Side	3	+0.7 (+0.07 to +2.6)	-4 (0 to -7)																					
G <sub>2</sub>	(Gomi et al., 2006)	BC	PR	Y	No-cut buffers (1 33 ft/10 m, 2 98 ft./30 m)	Mean (maximum) treatment effect summer maximum temp. (Table 3): 10 m: +1.0 (+4.1) °C; 30 m: +0.2 (+1.4) °C	X																	

H <sub>3</sub>	(Groom et al., 2011a)	OR (CR)	PR	Y	18 standard FPA prescriptions; 15 State Forest Management Plan (FMP) prescriptions	Avg. temp. change (text, p. 1626): FPA: 0.7 °C (range -0.9 to +2.5 °C); FMP: 0.0 °C (range -0.9 to +2.3 °C) Avg. change in shade (text p. 1627): FPA: -7%; FMP: -1%	X	X
I <sub>3</sub>	(Groom et al., 2011b)	OR (CR)	PR	Y	18 standard FPA prescriptions; 15 State Forest Management Plan (FMP) prescriptions	% chance of exceeding 0.3 °C FPA: 40; FMP: 9%	X	
J <sub>3</sub>	(Groom, 2013)	OR (CR)	IR	Y	18 standard FPA prescriptions; 15 State Forest Management Plan (FMP) prescriptions	Number of sites exceeding 16 or 18 °C criteria: 7	X	
K	(Hunter, 2010)	WA (Coast Ranges)	Gov't.	Y	7 hardwood conversions	Range in difference of mean GSF (pre-post, from text at each site): 0.03 to 0.13 Range in temperature changes (difference in temp. at upstream vs. downstream end of harvest unit, from figure for each site): -1.5 to +5.0 °C.	X	X
L <sub>4</sub>	(Jackson et al., 2007)	WA (Coast Ranges)	PR	N	3 no-cut buffers (7-69 ft.; 2-21 m); 2 nonmerchantable tree buffers	Change in cover (Table 4; average for both post-harvest years) no-cut: -54% (range: -15 to -78%); nonmerchantable tree: -58% (-35, -80%)		X
M <sub>4</sub>	(Jackson et al., 2001)	WA (Coast Ranges)	PR	Y	3 no-cut buffers (7-69 ft.; 2-21 m); 2 nonmerchantable tree buffers	Range in change in temperature (Table 3) no-cut buffers: -- 0.5 to +2.6 °C; nonmerchantable tree buffers: +2.8 to +4.9 °C	X	
N <sub>5</sub>	(Janisch et al., 2012)	WA (Coast Ranges)	PR	Y	6 no-cut buffers (33-49 ft.; 10-15 m); 5 patch buffers	Mean temperature disturbances (Figure 3b; range): no-cut: +0.7(0.0 to +1.9) °C; patch: +0.6 (+0.1 to +1.2) °C Change in canopy-topographic density (text p. 408), %: no-cut: -8; patch: -18	X	X
O <sub>2</sub>	(Kiffney et al., 2003)	BC	PR	Y	No-cut buffers (3 33 ft./10 m, 3 98 ft./30 m)	Difference in PAR, μmol/m <sup>2</sup> /s (Fig. 2): 10 m: +78 ; 30 m: +8 Increase in maximum summer water temperatures with respect to control reaches (text p. 1066): 10 m: 3 °C; 1.6 °C	X	X
P	(Martin, 2004)	SE AK	Gov't.	Y	3 RMAs with inner no-cut (25 ft.; 8 m) & outer partial cut (41 ft.; 12 m)	Avg. change in shade (difference pre-post means for each reach, Table 3): -29% (-24%, -26%, -38%)		X
Q	(Morman, 1993)	OR (BM, CR, EC, I, SC, WC, S(?))	Gov't.	Y	29 Variable-retention RMAs (25-100 ft.; 8-30 m)	Average change in shade for NW and S streams (Table top of p. 17, weighted for number of samples): -15%		X
R	(Newton and Cole, 2013a)	OR**	IR	Y	3 standard FPA prescriptions	Average maximum change in temperature over the reach: +0.7 °C (range: +0.3 to +2.0 °C)	X	

S <sub>1</sub>	(Newton and Cole, 2013b)	OR (CR,I)	PR	Y	4 shrub only buffers;	Average temperature differentials across 180 m shrub shade reaches: +1.6 °C (range +0.6 to +2.7 °C)	X	
T	(Rashin et al., 1992)	WA	Gov't.	Y	9 no-cut buffers (5-190 ft.; 1.5-58 m)	Range in median Max. water temp. differentials (Table 1): +0.1 to +4.6 °C	X	
U	(Schuett-Hames et al., 2012)	WA (Cascades, Coast ranges)	Gov't.	Y	13 with ½ of length no-cut buffers (50 ft.; 15 m), ½ length cut to stream edge; 3 with radial no-cut buffers at point of initiation of perennial flow (PIP) (56 ft. (17 m) radius)	Average change in shade (Table 49; average of 3 years difference between mean value for patch type and that of reference) 1/2-length no-cut buffers: -29% (range -24% to -38%); PIP: -30% (range -28% to -34%)		X
V	(Steinblums et al., 1984)	OR (I, WC)	PR	Y	40 no-cut buffers (25-115ft.; 8-35 m)	Fig. 2: Range in change in cover (Fig. 2; measured with respect to value at 140°): 0 to -73%		X
W	(Veldhuisen and Couvelier, 2006)	WA (N. Cascades)	Gov't.	Y	9 no-cut buffers (16-105 ft.; 5-32 m)	Range in change in shade (Appendix 4A, Upr Childs, Red Dog, Full Sail, Anchor Stm., WhiteWash; 10-31 m): -3 to -33%; Range in change in temp. (2 (Powell, Savage), & 3(Long Tom, RoundAgain, SingleShot, Appendices 4B (Powell, RedDog, AnchorStm, Grisdale, Miller Pt.) ; comparing 7DAD max. for buffers located downstream of forest): +1.0 to +8.3 °C	X	X
X <sub>5</sub>	(Wilk et al., 2010)	WA (Coast Ranges)	PR	N	7 no-cut buffers (33-49 ft.; 10-15 m); 3 patch buffers	Difference in canopy closure (Table 1): no-cut: -9%; patch buffers (average of patch (cut) and patch (leave) since same sites): -45%		X
Y <sub>1</sub>	(Zwieniecki and Newton, 1999)	OR (CR, I, WC)	PR	Y	6 standard FPA prescriptions; 5 hardwood conversions (HWCs); 3 HWCs limiting openings on south side of streams	For all prescriptions, no stat.sig. difference in shade; changes in temperature (differences between top and bottom of unit, averaged per prescription, from Fig.3) FPA: +1.3°C; HWC: +1.3 °C; S-sided HWC: +0.5 °C	X	X

\*Relates publications to ID for graphing purposes. Publications with the same subscript are from the same study (see Table 2).

† For studies located in Oregon, the Oregon Department of Forestry Georegions in which studies were completed is listed in parentheses; Georegions: CR=Coast Range; I=Interior; S=Siskyou; SC=South Coast; WC=West Cascades. Note: BM (Blue Mountains) and EC (East Cascades) are listed for informational purposes, although their data were not considered for this review.

\*\* (Newton and Cole, 2013a): unclear in which georegion, but west of the crest of the cascades.

†† Gov't.=government report (including OSU research papers not published in peer-reviewed journal); PR=peer-reviewed; IR=in review.

“ Is the study’s objective or questions directly relevant to this review’s question?

252 \*\*\*All forest harvests outside of buffers are clearcuts, except those of (Danehy et al., 2007) which were thinned from 200-300 down  
253 to 80 trees per acre.

**Draft Table 2. Publications with overlap of data from the same study.**

ID*	Study	Publications
1	W. Oregon	(Dent and Walsh, 1997; Newton and Cole, 2013b; Zwieniecki and Newton, 1999)**
2	BC	(Gomi et al., 2006; Kiffney et al., 2003)
3	RipStream	(Groom, 2013; Groom et al., 2011a, 2011b)
4	SW WA	(Jackson et al., 2001, 2007)
5	W. WA	(Janisch et al., 2012; Wilk et al., 2010)

\* For each set of studies, a number identifies it; these numbers are the subscripts which appear in Table 1 and Figures 1-12.

\*\* (Newton and Cole, 2013b) also included data from streams with different prescriptions and were not included in the previous two studies.

### ***3.2 Summary of studies and management prescriptions***

#### ***3.2.1 Summary of publications***

Of the 25 publications reviewed, 10 were governmental reports, 13 were peer reviewed journal articles, and 2 publications were unpublished and in review (Table 1). Of the publications considered to have a high focus on the Systematic Review (SR) question, they were evenly divided among those providing measures of temperature and those measuring shade (Table 4). However, government reports more often provided measures of shade (90% of publications) and peer review / in review articles more often provided measures of temperature (91% of publications). Only four publications were considered to have a low relevance, or be indirectly related, to the SR question and they were all peer reviewed articles that primarily measured shade (Completed Table A.6.3).

**Draft Table 3. Summary of publication measure and relevance to the primary review question.**

High Relevancy	Temperature	Shade	Both	Total
Government	1	5	4	<b>10</b>
Peer Review	4	1	4	<b>9</b>
In Review	2	-	-	<b>2</b>
<i>Sub-total</i>	<i>7</i>	<i>6</i>	<i>8</i>	<i>21</i>
Low Relevancy				
Peer Review	-	3	1	<b>4</b>
<b>Total</b>	<b>7</b>	<b>9</b>	<b>9</b>	<b>25</b>

### 3.2.2 Study design variability

Though there are 25 publications selected for review, several of the publications have overlapping study designs and share data (Table 2). For example, all three of the publications by lead author Groom utilize the same temperature dataset from the same study design, but explore different relationships. Another example of shared study designs is when Wilk et al. (2010) collected habitat data for wildlife and Janisch et al. (2012) looked more directly at stream temperature response due to management. Other situations with shared study designs include reporting on shade in one publication and temperature in another or returning to old study sites (e.g. Jackson et al., 2001,2007; Newton and Cole 2013b) .

### 3.2.3 Geographical ranges and physical settings

Due to the rule analysis selection criteria, all publications were limited to georegions within or similar to western Oregon. These georegions were selected due to similarities in climate, vegetation, and topography. Vegetation composition was generally dominated by Douglas-fir (*Pseudotsuga menziesii*), with sub-dominants such as red alder (*Alnus rubra*), big-leaf maple (*Acer macrophyllum*), and several conifer species. All but one of the publications chosen for the review had study sites west of the Cascades in Oregon, Washington and British Columbia or in the Siskiyou Mountains and many were set in multiple georegions (Table 1). The remaining publication was of a study conducted in Southeast Alaska. At least 11 publications had study

sites in the Oregon Coast Range, 4 in the western Cascades and 5 in the Interior (i.e. Willamette Valley and central Umpqua Valley). Nine of the studies had sites in western Washington, the majority of which were in the Coast Range (60-70% of the publications).

### **3.3 Measurements**

The primary systematic review question focuses on two factors associated with protecting core cold water habitat: 1) stream temperature and 2) riparian shade. Of the twenty-five publications reviewed, seven included only measurements of stream temperature, nine included only measures of riparian shade, and nine included measures of both stream temperature and riparian shade (Table 1). Stream temperature is a water quality parameter that can be measured directly using a number of sensing technologies; most commonly a thermometer, recording thermograph (a thermistor coupled with a data logging device), or, recently, fiber optics. Contrastingly, shade is difficult to measure directly because, for any given location, it changes both throughout the day and seasonally as a function of the position of the sun. Researchers have overcome this problem by using various measures of canopy density or light as proxies for shade (Davies-Colley and Payne, 1998).

All of the systematic review papers reporting stream temperature results collected time series of data measured at sub-daily intervals with recording thermographs. The duration of temperature data collection ranged from as little as two weeks (Danehy et al., 2007; Rashin, 1992) during the critical summer low flow period to year-round (Gomi et al., 2006; Kiffney et al., 2003). Measurement accuracy varied across studies for papers that actually reported such values, ranging from +/-0.2 to +/-1.0 °C. Resolution was only reported by Janisch et al. (2007) who had one sensor type with resolution of +/-0.16 and another with a resolution of 0.5 °C. As a frame of reference, most current sensors are advertised with +/-0.2 °C accuracy and 0.02 °C resolution. Many of the stream temperature analyses focused on relative differences between measurements made upstream and downstream of the riparian treatment before and after implementation such that measurement accuracy was not as critical as resolution in the statistical analysis. Notwithstanding, attention to reported measurement accuracy should be given when evaluating actual values of stream temperature extracted as a part of this systematic review.

Overhead canopy cover was measured with either a spherical densiometer (Dent, 2001; Dent and Walsh, 1997; Martin, 2004; Morman, 1993; Schuett-Hames et al., 2012; Veldhuisen and Couvelier, 2006; Zwieniecki and Newton, 1999) or via hemispherical photography (Allen and Dent, 2001; Dent and Walsh, 1997; Groom et al., 2011b; Hunter, 2010; Janisch et al., 2012; Wilk et al., 2010) while oblique canopy cover or angular canopy density (ACD) was measured with an angular canopy densiometer (Brazier and Brown, 1973; Steinblums et al., 1984). Despite the spherical densiometer being the most common device used to measure canopy cover, measurements obtained are subject to user-bias (Davies-Colley and Payne, 1998). Hemispherical photography is a less subjective means for quantifying canopy cover. However, multiple methods were used to analyze the photographs making direct comparison of results across studies difficult. Allen and Dent (1997), Groom et al. (2011a), and Hunter (2010) report hemispherical photography results as a Global Site Factor (GSF), the ratio of direct and diffuse energy at the point of the photograph to the total available direct and diffuse energy for that latitude, longitude, and day of year; Janisch et al. (2012) reports a Canopy and Topographic Density (CTD), a metric that, as its name implies, takes into account both the density of the canopy and the topographic obscurance; Wilk et al. (2010) presents the photographic analysis from the same study only as a canopy cover percent.

Photosynthetically active radiation (PAR; Kiffney et al., 2003) and solar insolation (Brososke et al., 1997; Danehy et al., 2007) are both measures that describe the amount of light reaching a certain point. Direct measures of light are sensitive to subtle changes in cloud cover and the position of the sun, a factor that was considered when evaluating the robustness of outcome measures of light reported by Brososke et al. (1997) and Kiffney et al. (2003). Danehy et al. (2007) estimated total solar insolation indirectly using hemispherical photography.

The secondary review question focused on how effects modifiers interact with near-stream forest management. In order to properly evaluate the influence of a particular effects modifier, formal inclusion in the statistical analysis was necessary. The most commonly evaluated effects modifiers were the length and width of the riparian reserve, stream width and depth, and stream gradient (see Table 4 for a full list). A number of publications presented data for variables that likely acted as effects modifiers without actually assessing their influence

statistically; most frequently, the types of trees, tree density, and stream/watershed aspect were reported but not evaluated (Table 4).

**Draft Table 4. Information on effects modifiers.**

First two columns list effects modifiers statistically analyzed for respective measure (i.e., column heading); number of publications for each effects modifier listed in parentheses. Effects modifiers from the protocol (Appendix A) that are not listed were not considered in any publications.

Temperature	Shade	Measured & Reported but not used in analysis
Length, width of riparian reserve (7)	Length, width of riparian reserve (10)	Types of trees (5)
Gradient (7)	Stream width/depth (6)	Tree density (5)
Stream width/depth (6)	Other riparian vegetation (5)	Aspect (5)
Aspect (4)	Gradient (5)	Tree/basal area retention (4)
Harvest on both or single sides of riparian reserve (4)	Discharge (3)	Time since harvest (4)
Canopy cover (4)	Substrate (3)	Discharge (4)
Discharge (3)	Gradient (3)	Length, width of riparian reserve (3)
Elevation (3)	Types of trees (2)	Logs or slash left in stream (3)
Air temperature (3)	Tree/basal area retention (2)	Windthrow (3)
Time of year (2)	Harvest on both sides or single side of riparian reserve (2)	Continuity of flow (3)
Substrate (2)	Logs or slash in stream (2)	Gradient (3)
Time since harvest (2)	Elevation (2)	Other riparian vegetation (2)
Types of trees (1)	Tree harvest in part of riparian reserve (1)	Canopy cover (2)
Residual stand composition (1)	Tree height, age (1)	Groundwater-surface water interactions (2)
Tree/basal area retention amount (1)	Crown height (1)	Elevation (2)
Other riparian vegetation (1)	Windthrow (1)	Air temperature (2)
Clearcut vs. thin (1)	Distance from stream source (1)	Tree height, age (1)
Distance from stream source (1)	Groundwater-surface water interactions (1)	Crown height (1)
Groundwater-surface water interactions (1)	Geology and soils (1)	Residual stand composition (1)
Flow through/from a wetland (1)	Time of year and season (1)	Method of tree removal (1)
	Air temperature (1)	Stream width/depth (1)

		Substrate (1)
		Geology and soils (1)

### 3.4 Statistical Analysis

Methods for analyzing temperature varied widely among the studies, dependent on the study design and measures selected for study. The majority of temperature studies included some type of statistical analysis of data, primarily analysis of variance (ANOVA) if differences between groups were considered by separating samples into groups prior to analysis (e.g. Dent and Walsh, 1997; Danehy et al., 2007) and regression analysis if the goal was to directly account for the effects of modifiers (e.g. Jackson et al., 2001; Veldhuisen and Couvelier, 2006; Groom et al., 2011b). A few of the studies used the measured data to develop predictive models to explore the importance of multiple effects modifiers, such as in Groom et al. (2011a,b; 2013) and Veldhuisen and Couvelier (2006). Autocorrelation of temperature time series data was addressed, but not consistently among the studies, which affected their statistical robustness score (Completed Table A.6.3).

Methods for analyzing shade were more consistent, with most of the studies conducting simple statistical tests of differences between either a control and the buffer type or a variety of buffer types. The exception tended to be if studies had too few samples for a statistical comparison or no control for comparison (e.g. Rashin et al., 1992; Martin, 2004; Hunter, 2010). For shade and cover studies, a sample was considered a control if it was collected pre-treatment or at a similar landscape unit at a nearby location.

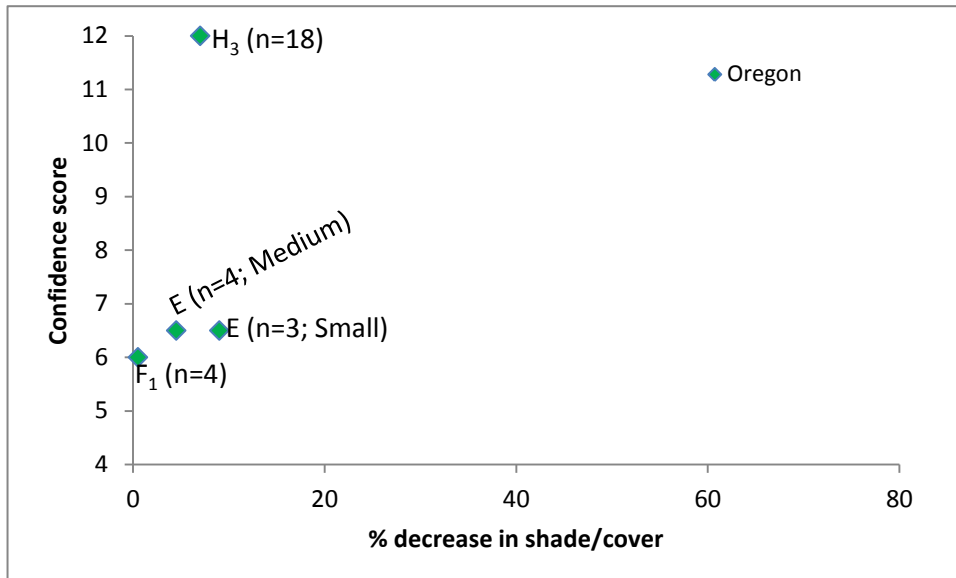
### 3.5 Rule Alternatives

Each reviewed paper was rated for relevance to the sixteen rule alternatives proposed by the Board of Forestry (Completed Table A.6.4). Seven of the sixteen rule alternatives had at least one highly relevant study (all had at least one study of low relevance). In the following sections, rule alternatives having highly relevant studies are discussed with respect to the range of variation in metrics defining each alternative, the range of variation in outcome measures, the degree of effectiveness at protecting against increases in stream temperature or riparian shade, and the overall confidence in the findings. Where applicable, the role of effects modifiers in influencing effectiveness is also addressed.

### 3.5.1 Forest Practices Act (FPA)

Seven publications covering five different studies were rated as highly relevant to describing changes to temperature and / or shade with harvest using FPA buffer management practices; nine publications were determined to have low relevance (Completed Table A.6.4). After leaving a 20 foot no-cut buffer, riparian buffers ranged from 20 to 130 feet, depending on the study (Dent and Walsh, 1997; Zwieniecki and Newton, 1999; Dent et al. 2001; Groom et al. 2011a,b; Groom 2013; Newton and Cole 2013a) . In some cases clearcut harvesting outside of the buffers occurred on both sides of the stream, but there were also cases where there was harvest on just one side of the stream. Tree retention within the buffer differs based on region, and though the majority of study sites were in the Coast Range, there were sites in the Interior and Western Cascades for all studies but those conducted by Groom et al. (2011a,b; 2013).

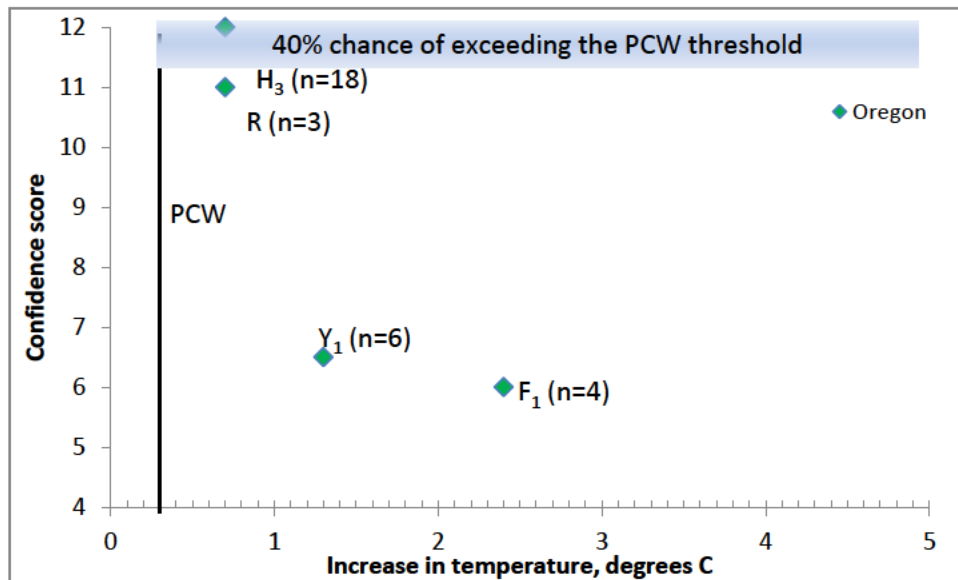
All studies reported an average decrease in shade or cover as a result of FPA management practices, regardless of whether it was a small or medium stream (Figure 1; Dent and Walsh, 1997; Dent et al. 2001; Groom 2011a). However, the change in shade ranged from a decrease of 18% to an increase of 11% (Dent and Walsh, 1997; Dent et al., 2001). Confidence in study design was low for the Dent and Walsh (1997) and Dent et al. (1999) studies, primarily due to low number of samples resulting in an inability to make robust statistical comparisons of the results. Due to the nature of the data collection method, there can be considerable error and thus variability in these measures leading to a wide range in results. Therefore, it is even more important to have larger sample sizes and differences in shade as low as 0.5% should be considered inconclusive.



**Draft Figure 1. Decrease in shade for sites with FPA buffers.**

Letter refers to publication ID (Table 1), n is the number of sites, and Small and Medium refer to stream size as defined in the FPA. Confidence score (a summary metric of study quality) is listed in Completed Table A.6.3; data on X-axis is listed in Table 1. Confidence scores (a summary metric of study quality) are listed in Completed Table A.6.3; data on X-axis are listed in Table 1.

Increases in temperature were also observed for all relevant studies, though the amount of increase varied (Figure 2). Groom et al. (2011a) and Newton and Cole (2013a) reported a temperature increase of 0.7 °C and there is high confidence that their results provide reliable information. Those studies with lower confidence in reported results had higher increases in their temperature: 1.3 °C (Zwieniecki and Newton, 1999) and 2.4 °C (Dent and Walsh, 1997). In all cases, the increase in temperature was greater than the PCW. Groom et al. (2011a) reported changes in temperature ranging from -0.9 to 2.4 °C, thus there is evidence that not all observed streams experienced an increase in temperature. Groom et al. (2011b; 2013) explored the probability of exceeding stream temperature criteria. The percent chance of a site managed using FPA rules exceeding the PCW rule was 40% and 7 out of 18 sites exceeded the 16 or 18 °C criteria for salmonids.



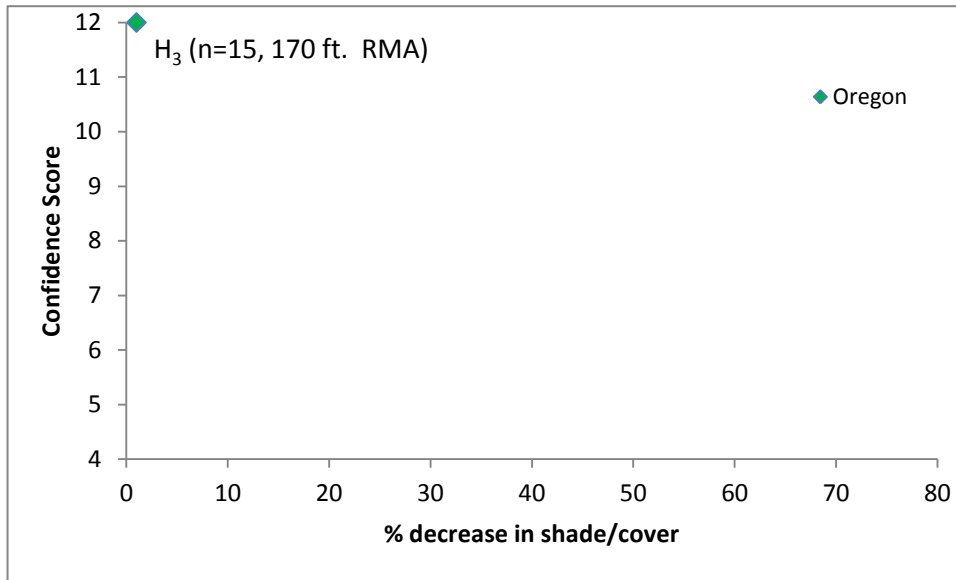
### **Draft Figure 2. Increase in temperature for sites with FPA buffers.**

Letter refers to publication ID (Table 1), n is the number of sites, PCW is the Protecting Cold Water criterion, and Small and Medium refer to stream size as defined in the FPA. Confidence scores (a summary metric of study quality) are listed in Completed Table A.6.3; data on X-axis are listed in Table 1.

#### **3.5.2 State Forest Management Plan (FMP)**

Three publications from one study (RipStream) contained highly relevant results of temperature and /or shade using the State Forest Management Plan (FMP) (Groom et al. 2011a,b, Groom et al. 2013); eleven publications were determined to have low relevance (Completed Table A.6.4). The highly relevant study was set in the Oregon Coast Range; therefore, all samples are from small and medium streams in a geographically similar area. Data was collected at 15 streams with a 25 foot no cut zone, limited harvest allowed within 100 feet of the stream to create mature forest with retention of 124 trees/ha, and tree retention of 25 to 111 conifer trees and snags/ha between 100 to 170 feet.

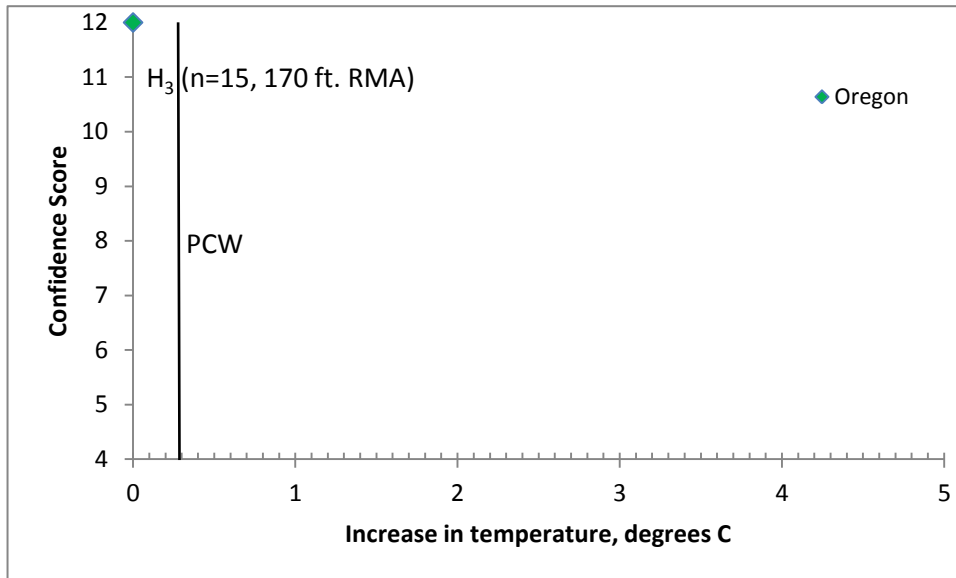
For the FMP sites of the RipStream study, shade comparisons were made pre- and post-harvest and there was no detectable change in shade post-harvest from pre-harvest conditions (mean decrease of 1%, n=15, p = 0.269) (Groom et al., 2011a). Shade pre- and post-harvest was between 80-95% for all sites.



**Draft Figure 3. Decrease in shade for sites with FMP buffers.**

Letter refers to publication ID (Table 1), n is the number of sites, and 170 ft. is the one-sided RMA (riparian management area) width. Confidence scores (a summary metric of study quality) are listed in Completed Table A.6.3; data on X-axis are listed in Table 1.

Findings from this study suggest there also are little to no noticeable changes in temperature using FMP practices. Changes in temperature were reported by looking at both change in temperature and probability of exceedances of criteria. Change in temperature at FMP sites was 0.0 °C (-0.9 to +2.5 °C) (Groom et al, 2011a). The chance of exceeding the 0.3 °C PCW criteria was found to be 9% and of the 15 sites, none exceeded the 16 °C or 18 °C criteria (Groom et al, 2011b; 2013). Strengthening the confidence in the results, data analysis for this study included measurement of effects such as discharge, length and width of the reserve, characteristics of the stand, landscape position and air temperature; therefore, taking into consideration a large number of the factors that have a high likelihood of influencing stream temperatures.

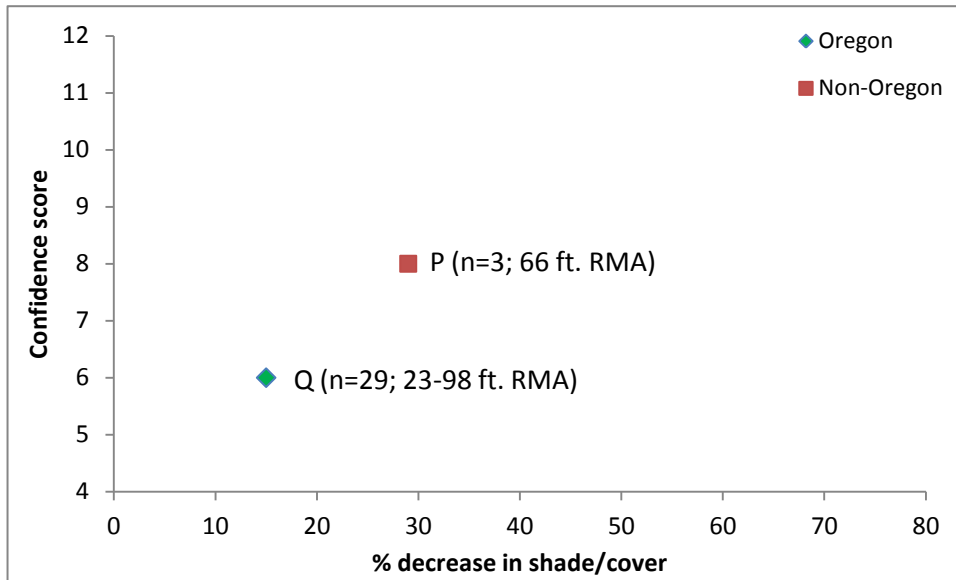


**Draft Figure 4. Increase in temperature for sites with FMP buffers.**

Letter refers to publication ID (Table 1), n is the number of sites, 170 ft. is the one-sided RMA (riparian management area) width, and PCW is the Protecting Cold Water criterion. Confidence scores (a summary metric of study quality) are listed in Completed Table A.6.3; data on X-axis are listed in Table 1. 9% change of exceeding PCW for sites with FMP buffers.

**3.5.3 Derived Variable Retention**

Two studies were highly relevant to the variable retention buffer rule alternative. Morman (1993) evaluated canopy density for twenty-nine variable retention buffers ranging from 25 to 100 feet in width in northwest and southern Oregon. Martin et al. (2004) measured stream temperature and riparian shade for three sites with 25-foot no-cut buffers and an additional 41-foot width of partial cut buffer in southeastern Alaska. The stream temperature control site was compromised, so only the shade data is considered in this synthesis. Six studies were considered to have low relevance to this rule alternative.



**Draft Figure 5. Decrease in shade for sites with variable retention buffers.**

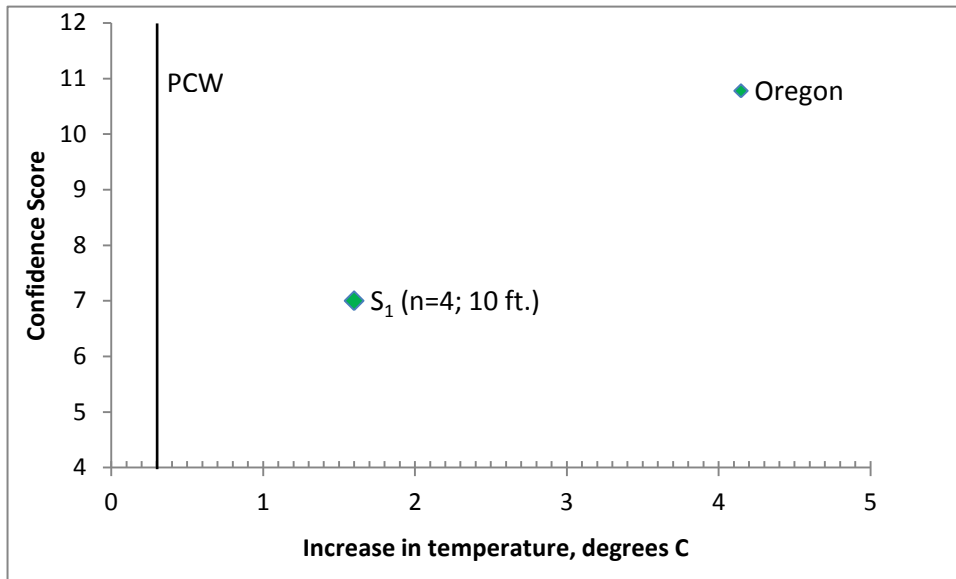
Letter refers to publication ID (Table 1), n is the number of sites, distance is the one-sided RMA (riparian management area) width. Confidence scores (a summary metric of study quality) are listed in Completed Table A.6.3; data on X-axis are listed in Table 1.

Both studies showed a decrease in shade where variable retention buffers were applied (Figure 5). Martin et al. (2004), who had a low sample size but a relatively sound study design, measured an average canopy density decrease of 29%. Morman (1993) used a larger sample size (29 sites) and found an average decrease of 15%. Morman's study evaluated the role of aquatic area width and hardwood versus conifers in relation to the amount of shade provided. However, despite the significantly larger sample size and assessment of effects modifiers, the confidence in the Morman study is lower than that of Martin et al. (2004)(Figure 5; Completed Table A.6.3). Additional data is required to definitively assess the effectiveness of this prescription at protecting stream shade.

#### **3.5.4 Shrub Shade**

Newton and Cole (2013b) provided highly relevant results for Shrub-Shade management practices by examining "no-tree buffers" (Completed Table A.6.4). In their study, different management practices were instituted along a length of stream where harvested and unharvested blocks lie adjacent to each other along the length of channel. Widths of the riparian reserve were

15 to 70 feet, depending on stream width, and interspersed with no-tree buffers along a harvested reach 600 feet long.



**Draft Figure 6. Increase in temperature for sites with shrub shade buffers.**

Letter refers to publication ID (Table 1), n is the number of sites, distance is the width of leaving shrubs, and PCW is the Protecting Cold Water criterion. Confidence scores (a summary metric of study quality) are listed in Completed Table A.6.3; data on X-axis are listed in Table 1.

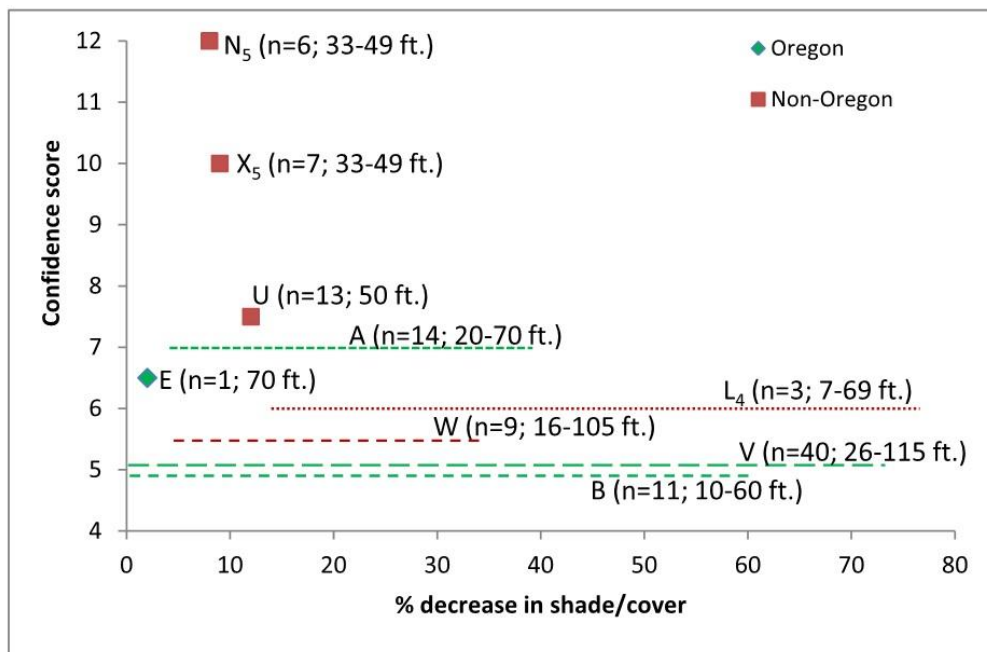
Stream temperature differentials increased in the no-tree buffers by an average of +1.6 °C (+0.6 to +2.7 °C) post-harvest (Newton and Cole 2013b; Figure 6). Effects considered when analyzing data include stand characteristics and some landscape characteristics, though sample sizes were low and the analysis method did not include formal statistical tests (they compared trendlines by site and year).

### **3.5.5 Derived No-cut Buffer**

The no-cut buffer was the most frequently studied rule alternative; twelve studies (fifteen publications) were rated as highly relevant and an additional four publications had low relevance (Completed Table A.6.4). Nine of the highly publications presented data on riparian shade, while ten included stream temperature data. Four of the nine highly relevant riparian shade publications presented data collected in Oregon (Allen and Dent, 2001; Brazier and Brown, 1973; Dent, 2001;

and Steinblums et al., 1984). However, only two of the ten stream temperature publications presented data collected in Oregon streams (Brazier and Brown, 1973; Danehy et al., 2007).

No-cut buffer widths in highly relevant riparian shade studies ranged from 7 to 115 feet per side (Figure 7; Completed Table A.6.2). The effectiveness of the no-cut buffer in preventing an increase in shade varied considerably. The two publications with the highest confidence score, Janisch et al. (2012) and Wilk et al. (2010), found that a continuous buffer, ranging from 33 to 49 feet (10 to 15 m), resulted in a 10% decrease in canopy density (both publications originated from the same study). Similarly, Schuett-Hames et al. (2012) measured an average canopy density reduction of 12% across thirteen 50-foot no-cut buffers in western Washington.



**Draft Figure 7. Decrease in shade for sites with no-cut buffers.**

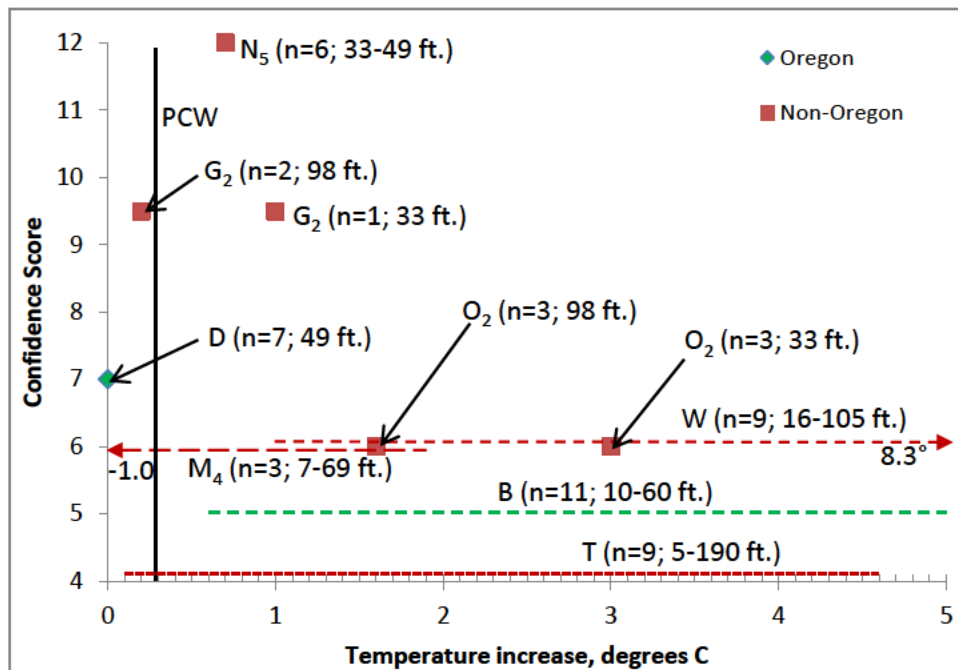
Letter refers to publication ID (Table 1), n is the number of sites, and distance is the no-cut buffer width. Dashed lines indicate a range of outcomes for sites for which averaging is inappropriate (e.g., due to different buffer widths). Confidence scores (a summary metric of study quality) are listed in Completed Table A.6.3; data on X-axis are listed in Table 1.

Several studies included multiple buffer widths in their assessment of riparian shade (Allen and Dent, 2001; Brazier and Brown, 1973; Jackson et al., 2007; Steinblums et al., 1984; Veldhuisen and Couvelier, 2006). A positive relationship between angular canopy density and

buffer width was evident in the data of both Brazier and Brown (1973) and Steinblums et al. (1984) despite considerable variability amongst the responses at individual measurement locations. Kiffney et al. (2003) found that solar insolation (PAR) was approximately 5-times greater in the 33-foot buffer than in the 98-foot buffer. Contrastingly, no strong positive relationship between canopy density and no-cut buffer width was visually evident in the data presented by Allen and Dent (2001) or Veldhuisen and Couvelier (2006) (no regression performed for no-cut data only). Jackson et al. (2007) caution against use of their canopy cover data because of concern that the survey reach was not necessarily representative of the entire stream; therefore, their results are not included in this narrative assessment (see Completed Table A.6.2 for results).

No-cut buffer widths in highly relevant stream temperature studies ranged from 5 to 190 feet and, as with the riparian shade studies, responses to treatment were highly variable (see Figure 8 and Completed Table A.6.2). Three publications reported results where the temperature response to a no-cut buffer was less than the PCW criterion: the 98-foot buffer of Gomi et al. (2006), the 49-foot buffer of Danehy et al. (2007), and one of the 26- to 33-foot buffers of Jackson et al. (2001). It should be noted that Danehy et al. (2007) measured temperature within the substrate and the Jackson et al. (2001) stream was significantly covered by blowdown. Gomi et al (2006) and Janisch et al. (2012) found that 33-foot and 33- to 49-foot no-cut buffers, respectively, resulted in an about a 1 °C increase in temperature over the study reach (these studies had the two highest confidence scores) while the 33-foot buffer of Kiffney et al. (2003) resulted in a 3 °C increase (a 1.5 °C increase was reported for their 98-foot buffer). Veldhuisen and Couvelier (2006) reported the largest temperature increase of all the highly relevant studies, an 8.3 °C increase in the maximum value of the 7-day moving mean of the daily maximum (buffer width unknown; it should also be noted that the forested controls had upstream-to-downstream increases ranging from +1.0 to +2.7 °C during the same monitoring period). The eleven sites of Brazier and Brown (1973) had a modest inverse relationship between temperature response and buffer width. The smallest differences in upstream-to-downstream temperature change (no information provided on the exact metric presented) were for a 60-foot and a 100-foot buffer (both had a 0.6 °C increase); however, one of the 100-foot no-cut buffers had a measured increase of 2.2 °C (note that although Brazier and Brown (1973) received a relatively

low confidence score, the temperature and buffer width data assessed here are considered robust).



**Draft Figure 8. Increase in temperature for sites with no-cut buffers.**

Letter refers to publication ID (Table 1), n is the number of sites, distance is the no-cut buffer width, and PCW is the Protecting Cold Water criterion. Dashed lines indicate a range of outcomes for sites for which averaging is inappropriate (e.g., due to different buffer widths). Confidence scores (a summary metric of study quality) are listed in Completed Table A.6.3; data on X-axis are listed in Table 1.

The publications reviewed showed that while no-cut buffers have the potential to protect against exceeding the PCW criterion, the generally implied notion that wider buffer widths provide better protection is not supported. The large degree of variability in the findings across studies limits confidence in pinpointing a specific no-cut buffer width that will be protective of the PCW criterion in all cases. The variability in magnitude of response is presumably related to the confounding role of effects modifiers in combination with the various buffer width treatments. Unfortunately, there was no consistency in evaluation of effects modifiers between studies. Janisch et al. (2012) found a significant correlation between mean daily temperature response and elevation, catchment area, aspect, channel gradient, channel length, depth, CTD,

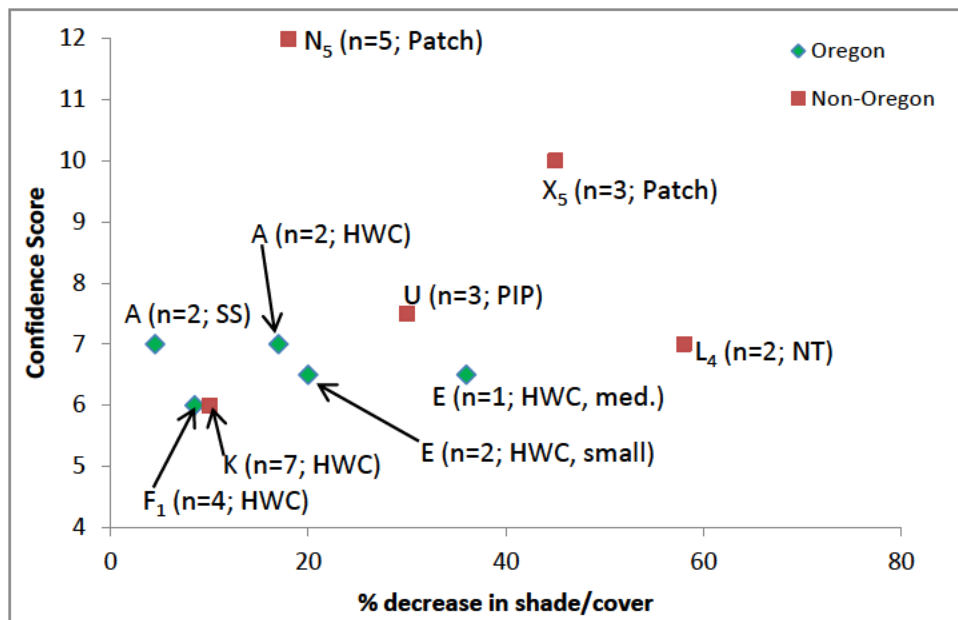
and percent of catchment with wetland. Veldhuisen and Couvelier (2006) also found significant relationships between temperature response and elevation and channel gradient plus percent shade but not for buffer width (however, their effects modifiers analysis included fully forested, clearcut, and debris flow streams). Several of the highly relevant publications reported temperature results from studies conducted in first-order, non-fish-bearing streams (Jackson et al., 2007; Janisch et al., 2012; Veldhuisen and Couvelier, 2006). Controls on water temperature in the extreme headwater reaches of a stream network are more variable than the dominant controls in larger downstream reaches (Jackson et al. 2007; Janisch et al, 2012); a factor that likely added to the variability in the response to treatment for this rule alternative.

### ***3.5.6 Plan for Alternative Practice***

Multiple alternative practices were considered in the reviewed publications. Hardwood conversion, patch, perennial initiation point, non-merchantable, and site-specific buffers were evaluated in riparian shade studies (three of the seven studies were conducted in Oregon); only hardwood conversion, patch, and non-merchantable buffers were assessed in stream temperature studies (two hardwood conversion studies from Oregon). Hardwood conversion buffers followed state-specified rules for converting hardwood-dominated buffers to conifer (Allen and Dent, 2001; Dent and Walsh, 1997; Dent, 2001; Hunter, 2010). Patch buffers had 164- to 360-foot sections of forested buffer with the rest of the catchment clearcut (Janisch et al., 2012; Wilk et al., 2010). Perennial initiation point buffers had a 56-foot radial buffer emanating from the point of perennial streamflow initiation (Schuett-Hames et al., 2012). Site-specific buffers were not well-defined, but were intended to “enhance and restore riparian areas” (Allen and Dent, 2001).

Effectiveness in protecting against decreases in riparian shade varied among the different alternative practices investigated (Figure 9). The most effective was the site-specific buffers, which had an average decrease in canopy density of 4.5%, but the confidence in this finding is limited by a low sample size (n=2). Hardwood conversion buffers resulted in a 10 to 20% reduction of canopy density for small streams (Allen and Dent, 2001; Dent and Walsh, 1997; Dent, 2001; Hunter, 2012), while the single medium hardwood conversion stream surveyed had a reduction of 36% (Dent, 2001). The patch buffers decreased canopy density by 18%, on average (Janisch et al., 2012; Wilk et al. (2010) reported a 45% reduction at the same study, but using a

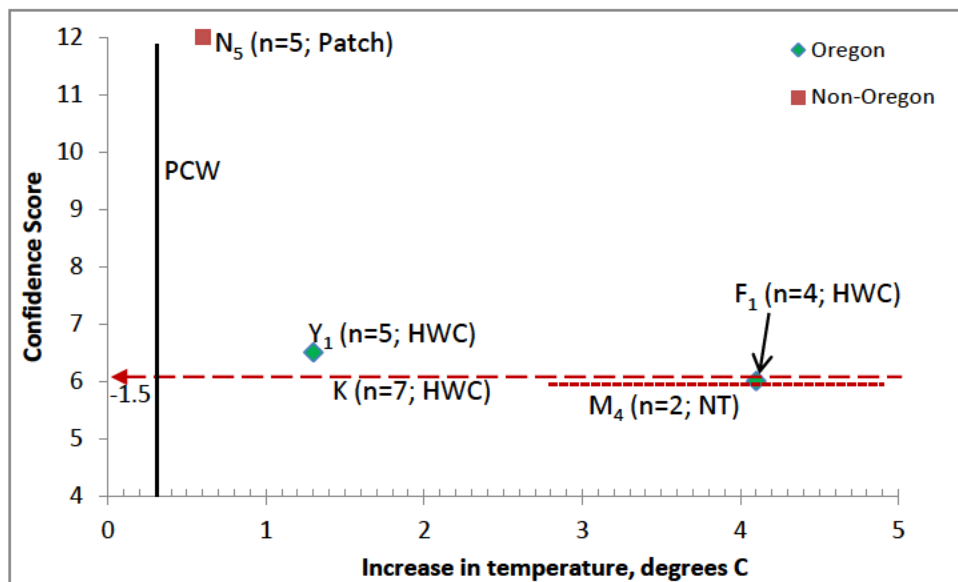
smaller sample size). The perennial initiation point and non-merchantable tree buffers were not generally effective, with 30% and 58% reductions in canopy densities, respectively (Jackson et al., 2007; Schuett-Hames et al., 2012).



**Draft Figure 9. Decrease in shade for sites with alternate practices buffers.**

Letter refers to publication ID (Table 1), n is the number of sites, and capital letters in parentheses refer to: HWC=hardwood conversion; NT=nonmerchantable tree; PIP=point of initiation of perennial flow; SS=site specific plan; and Patch are buffers left in patches along sensitive reaches. Confidence scores (a summary metric of study quality) are listed in Completed Table A.6.3; data on X-axis are listed in Table 1.

Only one measurement location in all of the alternative practices studies prevented a PCW criterion exceedance, a patch buffer with an increase of 0.1 °C (Figure 10; Janisch et al., 2012); the average temperature increase for the patch buffers was 0.7 °C (n=5). Hardwood conversion buffers resulted in a wide range of temperature responses, spanning from a decrease in temperature of 1.5 °C (Hunter et al., 2012) to increases in excess of 5 °C (Hunter et al., 2012; Dent and Walsh, 1997). Non-merchantable buffers were also not generally effective with measured increases of 2.8 and 4.9 °C (Jackson et al., 2001).



**Draft Figure 10. Increase in temperature for sites with alternate practices buffers.**

Letter refers to publication ID (Table 1), n is the number of sites, PCW is the protecting cold water criterion, and capital letters in parentheses refer to: HWC=hardwood conversion; NT=nonmerchantable tree; PIP=point of initiation of perennial flow; SS=site specific plan; and Patch are buffers left in patches along sensitive reaches. Dashed lines indicate a range of outcomes for sites for which averaging is inappropriate (e.g., due to different buffer widths). Confidence scores (a summary metric of study quality) are listed in Completed Table A.6.3; data on X-axis are listed in Table 1.

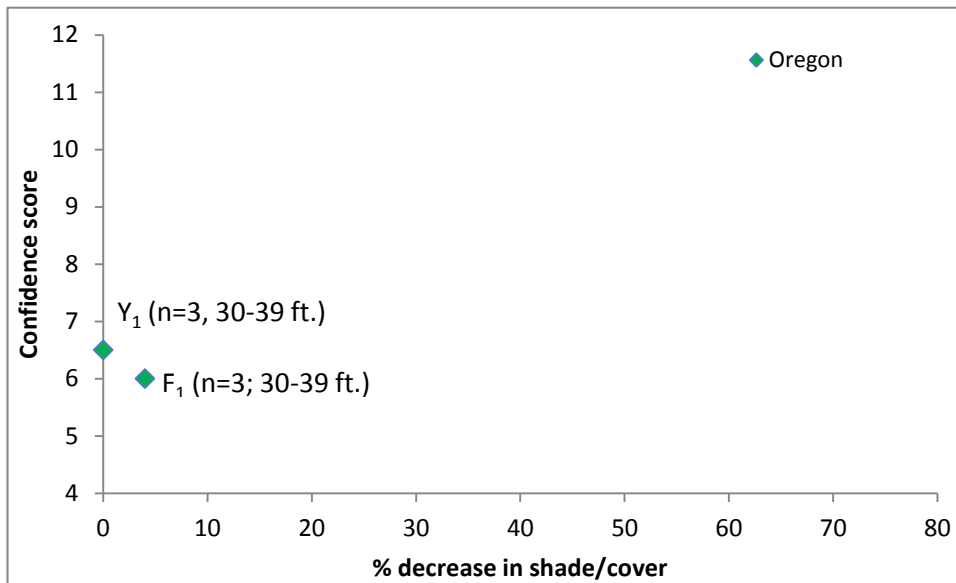
Information on specific alternative practices is too sparse to make a definitive assessment as to the true effectiveness of each. It appears that non-merchantable and perennial initiation point buffers did not meet the PCW. Hardwood conversion buffers, for which the greatest amount of information exists, along with site-specific and patch buffers have the potential to protect against PCW exceedance. However, additional study is needed, with particular focus given to controlling for effects modifiers such that the design specifications necessary to provide adequate protection to the stream can be constrained.

### 3.5.7 One-sided Buffer

Two different studies located at the same sites during the same timeframe describe three hardwood conversion units with limited openings on the south side of stream (Dent and Walsh, 1997; Zwieniecki and Newton, 1999). Two of the three sites were in the Oregon Coast

Range. Buffer widths ranged from 18 to 131 feet and harvest units were between 1100 feet to nearly one mile in length; the sites were harvested according to 1994 stream rules.

Dent and Walsh (1997) described a 4% (0-7%) decrease in cover at the sites post-harvest, but Zwieniecki and Newton (1999) reported no difference in shade post-harvest. Considering the difference in results, the range of variability for shade measures and the low sample size, these results are relatively inconclusive.



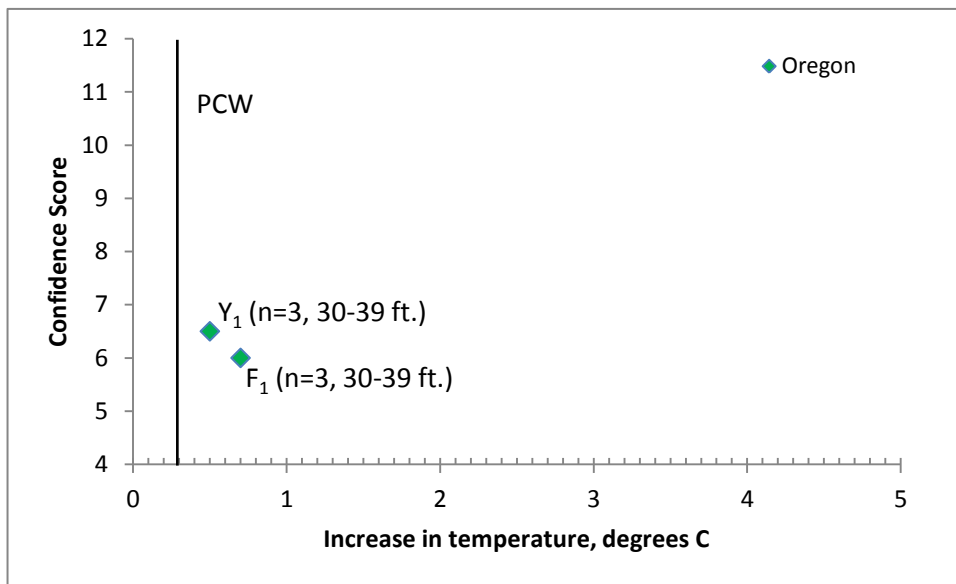
**Draft Figure 11. Decrease in shade for sites with south-sided buffers.**

Letter refers to publication ID (Table 1), n is the number of sites, and distance is the width of buffer. Confidence scores (a summary metric of study quality) are listed in Completed Table A.6.3; data on X-axis are listed in Table 1.

Despite small changes in cover, stream temperatures increased above the PCW criteria. Both studies showed an increase in stream temperature post-harvest: 0.7 °C (+0.07 to +2.6 °C; Dent and Walsh, 1997) and 0.5 °C (Zwieniecki and Newton, 1999; Table 1). Differences in results are likely due to differences in sampling method. Both studies collected the 7 day moving mean maximum temperature, but sampling occurred in July and August for Zwieniecki and Newton (1999) and generally between July and early September for Dent and Walsh (1997). Regardless, sample sizes were low and results by individual site are not conclusive of a general

trend of increase in temperature (Completed Tables A.6.2). Reanalysis of data by Newton and Cole (2013b) suggest more confidence that warming occurred post-harvest.

These studies took into consideration stream characteristics, landscape position and stand characteristics such as buffer width and cover. Zwieniecki and Newton (1999) modeled behavior from multiple prescriptions using the effects modifiers; however, the sample size for one-sided buffers is too small to encompass the variability and compare differences between treatments in a statistical test.



**Draft Figure 12. Increase in temperature for sites with south-sided buffers.**

Letter refers to publication ID (Table 1), n is the number of sites, distance is the width of buffers, and PCW is the protecting cold water criterion. Confidence scores (a summary metric of study quality) are listed in Completed Table A.6.3; data on X-axis are listed in Table 1.

### 3.6 Study Limitations and Knowledge Gaps

Although a relatively significant amount of information is available regarding stream temperature and riparian shade responses to forest management, the ability to identify emergent trends across studies is hampered by several factors. The primary limitation is the inconsistencies between study designs and analysis methodologies, particularly the adequate measurement and incorporation of effects modifiers into the assessment. Deciphering observed differences in

response between similar buffer designs is extremely difficult if effects modifiers have not been controlled for in the study design and analysis. A somewhat related limitation is the use of a variety of response metrics. This primarily applies to stream temperature studies where the time series of temperature data can be reduced or averaged in many ways but is also applicable to shade studies where different methodologies for collecting and processing canopy density data generate different metrics, such as canopy density percent, global site factor, and canopy and topographic density. Results are more difficult to compare across studies when the response metrics utilized are dissimilar. The generally low sample sizes (especially within buffer management types) and inconsistency in utilization of effects modifiers made traditional statistical models inappropriate, also making comparisons between studies challenging. Another study design-related limitation is that a several studies collected a wealth of data but offered very little for inferring their results to other locations because they were essentially designed as a series of single stream case studies (Rashin et al., 1992; Dent and Walsh, 1997; Martin, 2004; Hunter, 2010).

A major finding of this SR effort is the lack of studies that were highly relevant to proposed rule alternatives other than the no-cut buffer. Twelve different studies investigated no-cut buffers of various widths compared to only three for the current FPA and only one for the current State Forests standards. Seven studies were highly relevant to the Alternative Practices rule alternative, but within that category the most studies related to any one specific alternative practice was three (hardwood conversion). Nine rule alternatives did not have any highly relevant studies. Low relevance studies were generally more numerous across the rule alternatives. However, extracting usable information from low relevance studies is extremely challenging and highly prone to mischaracterization.

Several studies were not focused directly on the SR-related questions of stream temperature or riparian shade response to forest management and data relevant to this effort were collected indirectly (e.g. Brosnoff et al, 1997; Danehy et al., 2007; Jackson et al., 2007; Wilk et al., 2010). Though these studies were considered highly relevant to at least one rule alternative, sample sizes were small (Wilk et al., 2010), no pre-treatment data was collected (Brosnoff et al., 1997), and their lack of direct focus perhaps limited confidence in the findings.

#### 4. Draft Lessons Learned – External Scientists’ Perspective

Utilization of the systematic review process is still being tested and several lessons were learned that may help inform future review efforts.

First, the process employed in this systematic review was helpful in initiating conversation between the reviewers. The process included an initial review of four publications that were compared between reviewers. Comparing reviews resulted in conversation about terminology, discussion of how tables should be completed, and a shared understanding of definitions. It would be useful for the four review papers to provide a spectrum of challenges and test the range of definitions so that reviewers are also better prepared.

As with any new process, methods can be developed but are not reliable until they have been tested. Time and resources on behalf of the reviewers may have been saved if definitions and tables were tested prior to engaging the reviewers. If there is a desire to standardize tables, it might also be useful to provide an example of the type of information to be collected in the table, possibly using an example of one of the papers not chosen for inclusion in the study.

The systematic review question is focused on meeting the information needs of policy-makers; however, few of the studies were conducted specifically to answer the question posed. The uniqueness of the studies made it challenging to compare data and to answer the systematic review question. As described in Study Limitations, the vast difference in study designs made it challenging to objectively assess the study design and statistical methods. For example, sample sizes were frequently low; effects modifiers were often collected, but not always analyzed; if there was pre-treatment data, it was frequently only for one year, which may be adequate for assessing shade, but may not be adequate for temperature.

For a systematic review question as focused as it was for this study, it may have been more advantageous to search specifically for studies that could answer the management question posed. It is hard to understand whether or not the full spectrum of studies for a given buffer management type was explored, when there appeared to be a heavy balance towards particular buffer management types (i.e. FPA, derived no-cut). Also, there were studies that fell into the category of “Plan for alternative practice” which cannot be easily compared to each other or any of the other buffer management types; therefore, they are essentially not useful to this review.

Finally, reading and understanding a study well enough to summarize it takes time. Results can be skimmed through and extracted relatively quickly, but to be able to understand the context of those results so that they can be compared to other studies takes more effort in reading and interpretation. For example, a temperature increase of 0.7 °C can be extracted looking at figures and tables, but management practice and effects modifiers need to be considered, as well as data collection methods and statistical analysis methods. Furthermore, once this data has been gleaned from a paper or report, additional time needs to be made to assess comparisons between studies, especially when methods can be substantially different from each other. We recommend time be allowed for the reviewer to re-familiarize themselves with the papers prior to writing, as it will necessarily take some time from the review of the first papers to the time when writing must begin. Mechanisms for reducing this need for additional review should be considered.

## ***5. Draft References***

- Allen M, Dent L. 2001. Shade conditions over forested streams in the Blue Mountain and Coast Range georegions of Oregon . Oregon Department of Forestry
- Bowler D, Hannah D, Orr H, Pullin A. 2008. What are the effects of wooded riparian zones on stream temperatures and stream biota? . CEE Review. Collaboration for Environmental Evidence [online] Available from: [http://www.environmentalevidence.org/Documents/Final\\_protocols/Protocol45.pdf](http://www.environmentalevidence.org/Documents/Final_protocols/Protocol45.pdf)
- Brazier JR, Brown GW. 1973. Buffer strips for stream temperature control . OSU School of Forestry: Corvallis, OR
- Brosofske KD, Chen J, Naiman RJ, Franklin JF. 1997. Harvesting effects on microclimatic gradients from small streams to uplands in western Washington. Ecological applications **7** : 1188–1200.
- Brown GW. 1969. Predicting temperatures of small streams. Water Resources Research **5** : 68–75.
- Brown GW, Krygier JT. 1970. Effects of clear-cutting on stream temperature. Water Resources Research **6** : 1133–1139.
- Burnett KM, Giannico GR, Behan J. 2008. A Pilot Test of Systematic Review Techniques: Evaluating Whether Wood Placements in Streams of the Pacific Northwest Affect Salmonid Abundance, Growth, Survival or Habitat Complexity . Final Report on Findings. Institute for

784 Natural Resources, Oregon State University: Corvallis, OR [online] Available from:  
 785 <http://oregonstate.edu/inr/Burnett-2008> (Accessed 14 November 2012)

786 Centre for Evidence-based Conservation. 2010. Guidelines for Systematic Review in  
 787 Environmental Management, version 4.0

788 Danehy RJ, Chan SS, Lester GT, Langshaw RB, Turner TR. 2007. Periphyton and  
 789 macroinvertebrate assemblage structure in headwaters bordered by mature, thinned, and clearcut  
 790 Douglas-fir stands. *Forest Science* **53** : 294–307.

791 Davies-Colley RJ, Payne GW. 1998. Measuring stream shade. *Journal of the North American*  
 792 *Benthological Society* **17** : 250–260.

793 Dent L. 2001. Harvest effects on riparian function and structure under current Oregon Forest  
 794 Practice Rules

795 Dent LF, Walsh JBS. 1997. Effectiveness of riparian management areas and hardwood  
 796 conversions in maintaining stream temperature. *Forest Practices Technical Report* **3**

797 Fazey I, Salisbury JG. 2002. Evidence-based environmental management: What can medicine  
 798 and public health tell us? presented at the National Institute for the Environment, Australian  
 799 National University. Canberra, Australia. 24 June

800 Gomi T, Moore RD, Dhakal AS. 2006. Headwater stream temperature response to clear-cut  
 801 harvesting with different riparian treatments, coastal British Columbia, Canada. *Water Resources*  
 802 *Research* **42** DOI: W08437 Artn w08437 [online] Available from: [://000240338800001](http://www.waterresourcesresearch.org/000240338800001)

803 Groom JD. 2013. Timber harvest and the assessment of Oregon's Biologically-Based Numeric  
 804 Criteria in Coast Range streams (in prep)

805 Groom JD, Dent L, Madsen LJ, Fleuret J. 2011a. Response of western Oregon (USA) stream  
 806 temperatures to contemporary forest management. *Forest Ecology and Management* **262** : 1618–  
 807 1629.

808 Groom JD, Dent L, Madsen LJ. 2011b. Stream temperature change detection for state and private  
 809 forests in the Oregon Coast Range. *Water Resources Research* **47** [online] Available from:  
 810 [http://www.scopus.com/inward/record.url?eid=2-s2.0-](http://www.scopus.com/inward/record.url?eid=2-s2.0-78651287146&partnerID=40&md5=9d7b88edf8674f311f225f94a1e73358)  
 811 [78651287146&partnerID=40&md5=9d7b88edf8674f311f225f94a1e73358](http://www.scopus.com/inward/record.url?eid=2-s2.0-78651287146&partnerID=40&md5=9d7b88edf8674f311f225f94a1e73358)

812 Hale VC. 2007. A physical and chemical characterization of stream water draining three Oregon  
 813 Coast Range catchments

814 Hunter MA. 2010. Water Temperature Evaluation of Hardwood Conversion Treatment Sites  
 815 Data Collection Report [online] Available from:  
 816 [http://www.dnr.wa.gov/Publications/fp\\_cmer\\_05\\_513.pdf](http://www.dnr.wa.gov/Publications/fp_cmer_05_513.pdf) (Accessed 19 February 2013)

817 Jackson CR, Batzer DP, Cross SS, Haggerty SM, Sturm CA. 2007. Headwater streams and  
818 timber harvest: channel, macroinvertebrate, and amphibian response and recovery. Special issue:  
819 Science and management of forest headwater streams **53** : 356–370.

820 Jackson CR, Sturm CA, Ward JM. 2001. Timber harvest impacts on small headwater stream  
821 channels in the coast ranges of Washington. Journal of the American Water Resources  
822 Association **37** : 1533–1549.

823 Janisch JE, Wondzell SM, Ehinger WJ. 2012. Headwater stream temperature: Interpreting  
824 response after logging, with and without riparian buffers, Washington, USA. Forest Ecology and  
825 Management **270** : 302–313.

826 Johnson SL. 2004. Factors influencing stream temperature in small streams: Substrate effects  
827 and a shading experiment. Canadian Journal of Fisheries and Aquatic Science **57 (Suppl. 2)** :  
828 30–39.

829 Johnson SL, Jones JA. 2000. Stream temperature responses to forest harvest and debris flows in  
830 western Cascades, Oregon. Canadian Journal of Fisheries and Aquatic Sciences **57** : 30–39.

831 Kiffney PM, Richardson JS, Bull JP. 2003. Responses of periphyton and insects to experimental  
832 manipulation of riparian buffer width along forest streams. Journal of Applied Ecology **40** :  
833 1060–1076.

834 Martin DJ. 2004. The Effectiveness of Riparian Buffer Zones for the Protection of Water Quality  
835 and Fish Habitat in Michael Creek . Alaska Department of Natural Resources: Juneau, AK

836 Morman D. 1993. Riparian rule effectiveness study report . Forest Practices Program, Oregon  
837 Department of Forestry [online] Available from: <http://www.getcited.org/pub/100206391>  
838 (Accessed 19 February 2013)

839 Newton M, Cole EC. 2013a. Influence of Streamside Buffers on Near-Stream Environment  
840 Following Clearcut Harvesting in Western Oregon. in prep

841 Newton M, Cole EC. 2013b. Stream temperature and streamside cover 14-17 years after  
842 clearcutting along small forested streams, western Oregon. Western Journal of Applied Forestry  
843 **in press**

844 Oregon Department of Environmental Quality (ODEQ). 2004. Final temperature rule and other  
845 water quality standards revisions

846 Oregon Department of Forestry. 1994. FP Technical Note 1: Water Classification

847 Oregon Department of Forestry. 2010. Forest Practices Administrative Rules

848 Rashin E, Washington (State), Watershed Assessments Section. 1992. Effectiveness of  
849 Washington’s forest practice riparian management zone regulations for protection of stream

850 temperature / Graber, Craig. . Washington State Dept. of Ecology, Environmental Investigations  
851 and Laboratory Services Program, Watershed Assessments Section: Olympia, Wash.

852 Richter A, Kolmes SA. 2005. Maximum temperature limits for chinook, coho, and chum salmon,  
853 and steelhead trout in the Pacific Northwest. *Reviews in Fisheries Science* **13** : 23–49.

854 Schuett-Hames D, Roorbach A, Conrad R. 2012. Results of the Westside Type N Buffer  
855 Characteristics, Integrity and Function Study Final Report [online] Available from:  
856 [http://www.dnr.wa.gov/Publications/fp\\_cmer\\_12\\_1201.pdf](http://www.dnr.wa.gov/Publications/fp_cmer_12_1201.pdf) (Accessed 19 February 2013)

857 Sinokrot BA, Stefan HG. 1993. Stream temperature dynamics: measurements and modeling.  
858 *Water Resources Research* **29** : 2299–2312.

859 Steinblums IJ, Froehlich HA, Lyons JK. 1984. Designing stable buffer strips for stream  
860 protection. *Journal of Forestry* **82** : 49–52.

861 Veldhuisen C, Couvelier D. 2006. Summer Temperatures of Skagit Basin Headwater Streams:  
862 Results of 2001 – 2003 Monitoring

863 Wilk RJ, Raphael MG, Nations CS, Ricklefs JD. 2010. Initial response of small ground-dwelling  
864 mammals to forest alternative buffers along headwater streams in the Washington Coast Range,  
865 USA. *Forest ecology and management* **260** : 1567–1578.

866 Zwieniecki MA, Newton M. 1999. Influence of streamside cover and stream features on  
867 temperature trends in forested streams of western Oregon. *Western Journal of Applied Forestry*  
868 **14** : 106–113.

869

870

## **D.2 Additions to the draft report**

### ***Draft Executive Summary***

#### ***Draft ES 1. Introduction***

##### ***ES 1.1 Background***

The Oregon Department of Forestry (ODF) has undertaken a systematic science review in support of a riparian rule analysis process to address concerns about Oregon Department of Environmental Quality (DEQ) stream temperature standards. Specifically, the Oregon Board of Forestry (“Board”) made a decision in January 2012 that stream protections afforded to small and medium sized fish-bearing streams under the Forest Practices Act (FPA) were not likely

protective of the DEQ Protecting Cold Water (PCW) criterion. This criterion prohibits human activities such as timber harvest from increasing stream temperatures by more than 0.3 °C at locations critical to salmon, steelhead or bull trout. This finding of degradation was due to scientific outcomes of the Oregon Department of Forestry (ODF) Riparian and Stream Function (RipStream) monitoring project. The geographic scope of the RipStream findings is limited to streams in the Coast Range and Interior Geographic Regions of Oregon (as defined in OAR 629-635-0220). While the exact geographic extent of the rule analysis is yet to be determined, it will be limited to western Oregon. This limitation is due to the vegetation, climate and hydrologic characteristics of eastern Oregon being significantly different enough from those included in the RipStream study to preclude extending a rule change to eastern Oregon. At their July 2012 meeting, the Oregon Board of Forestry approved consideration of 16 rule alternatives (contributed by stakeholders) for meeting the PCW standard during harvest operations.

### ***ES 1.2 Objective of the Review***

This systematic review is designed to provide scientific guidance to the Board on the efficacy of the 16 rule alternatives in addressing the following rule analysis objective developed by the Board at their April 2012 meeting:

**Establish riparian protection measures for small and medium fish-bearing streams that maintain and promote shade conditions that insure, to the maximum extent practicable, the achievement of the Protecting Cold Water criterion.**

A secondary purpose of this review is to inform the Board's decision on the geographic extent of the rule analysis process.

### ***Draft ES 2. Methods***

A protocol for this systematic review was developed following guidance on conducting systematic reviews in the natural resource sciences. This protocol provided a road map for how to conduct the review of scientific literature relevant to the focused question:

**For small and medium streams in the western Pacific Northwest, in or adjacent to forest harvest operations, what are the effects of near-stream forest management on stream temperature and/or riparian shade?**

The review seeks to answer this question with evidence, as opposed to the authors' interpretation of such evidence, from existing studies. These studies are rigorously screened for quality and relevance to this question. The protocol provides for rigor and transparency concerning how studies are searched for, which ones are included in the review, and how they are analyzed. This process also allows for a review to be either updated in the future, or completed by another party. Finally, the entire process of conducting the review allows for greater inclusion of review partners (e.g., stakeholders and technical experts). All steps of the review are fully documented for transparency and input from review partners. These partners (e.g., agency personnel, conservation stakeholders, industry experts) strengthened the quality of this systematic review.

To minimize bias in the review, ODF hired external scientists to conduct the review and write this report synthesizing their analyses. ODF coordinated the work of the reviewers and all other partners, and wrote portions of this report.

### ***Draft ES 3. Results and Synthesis***

The systematic search found 1,456 publications, of which 25 passed all the inclusion criteria for the review. Of included publications, 10 were governmental reports, 13 were peer reviewed journal articles, and two documents were unpublished and in review. Since several of the publications are from the same study, these 25 publications represent 19 distinct studies. The publications were divided between those measuring shade only (7), temperature only (7), or both (9).

#### ***ES 3.1 Geographical ranges and physical settings***

Due to the geographically-focused review question, all publications were limited to areas within, or similar to, Oregon west of the crest of the Cascade Range. Considered in terms of ODF Geographic Regions: twelve publications had study sites in the Coast Range, two in the Western Cascades, and eleven in the Interior.

To gain insight on geographic extent of the rule analysis, effectiveness of buffer prescriptions were compared between ODF Geographic Regions. Analysis could not discern a pattern of effectiveness being different in any particular Geographic Region for the various

buffer prescriptions. The inability to discern a pattern may be influenced by the small amount of data available for robust comparisons.

### ***ES 3.2 Rule Alternatives***

Each publication in this review was rated for relevance to the sixteen rule alternatives proposed by the Board. Seven of the sixteen rule alternatives had at least one highly relevant study (i.e., the study provides quantitative data that addresses the effectiveness of a particular prescription of a rule alternative at protecting stream temperature or shade). In contrast, nine rule alternatives had no studies that were highly relevant to them. All rule alternatives had at least one study of low relevance. Eleven studies were highly relevant to more than one rule alternative. Only rule alternatives that had highly relevant studies are included in this analysis because they provide evidence of buffer effectiveness. The nine rule alternatives without highly relevant studies are not examined because they lack evidence concerning their ability to protect cold water and shade in western Oregon.

Only two classes of rule alternatives had studies that were high quality and were clearly effective at protecting cold water: Derived Variable Retention (which includes State Forest Management Plan [FMP] as a particular prescription) and No-cut buffers. For the FMP, the only study considered had a high confidence score (a measure of study quality), and protected both shade (average change in shade: -1%) and temperature (average change in temperature: 0.0 °C). Another specific prescription of a variable retention buffer, the Forest Practices Act (FPA), was assessed. All averaged data from each of the four FPA studies ranged for change in % shade between -0.5 and -9%, yet none of those with temperature data met the PCW standard. Confidence scores for these studies ranged from low to high. Of the other two variable retention prescriptions tested, the only one that had some sites that appeared to protect shade was based on the ODF riparian rules from before 1994. However, the average change in shade was -19% and the confidence score was low (temperature data were not collected for this study).

The No-cut buffers were the most-extensively studied (12 studies) of all the rule alternatives. Nearly all studies that examined shade had some sites wherein shade was protected, and their confidence scores ranged from low to high. However, it should be noted that many of the studies included a wide range of buffer widths and thus their data could not be averaged in a

meaningful way. Four of seven studies that measured stream temperatures had some sites that met the PCW standard, three of which had a range of buffer widths.

Three other rule alternatives were assessed for their effectiveness at protecting cold water and/or shade. The shrub shade alternative had a low quality study with three sites, and came close to, but did not achieve, the PCW standard. Similarly, the south-sided buffers had one study of low quality with three sites. The results show this buffer was protective of shade, and came close to, but did not achieve, the PCW standard.

The final rule alternative, plan for alternate practices, acts as a catch-all for riparian management prescriptions that did not fit into other rule alternatives. As such, it includes six different prescriptions analyzed in seven studies. Two prescriptions (undefined “site specific” plans, and hardwood conversions (HWC) following each of Washington and Oregon’s rules) had sites wherein shade was protected (low to medium confidence scores), and only Washington’s HWC (low confidence score) had some sites wherein the PCW standard was met.

### ***ES 3.3 Summary***

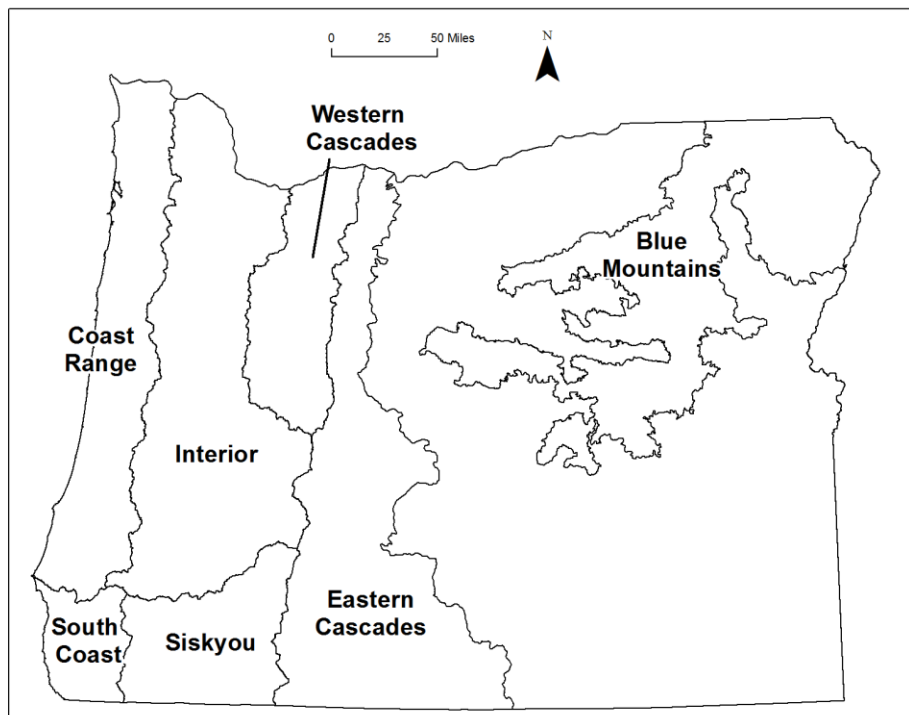
This review provides two key components that inform the Riparian Rule Analysis:

1. Nineteen studies have assessed the effectiveness of riparian buffers to protect cold water or shade in forest harvest operations in the Pacific Northwest. These studies vary widely in both their designs and their quality.
2. The evidence from this suite of studies only supports two classes of rule alternatives as effective in meeting the Protecting Cold Water standard:
  - A. Variable retention buffers (including State Forest Management Plan)
  - B. No-cut buffers

#### ***3.2.3 Draft Geographical ranges and physical settings***

Due to the selection criteria for this review, all publications were limited to areas within, or similar to, Oregon west of the crest of the High Cascades. These areas were selected due to their similarities in climate, vegetation, hydrology, and topography with those from the study (Groom *et. al*, 2011b) that initiated this rule analysis. Vegetation composition was generally dominated by Douglas-fir (*Pseudotsuga menziesii*), with sub-dominants such as red alder (*Alnus*

*rubra*), big-leaf maple (*Acer macrophyllum*), and several conifer species. All but one of the publications chosen for the review had study sites west of the Cascades in Oregon, Washington and British Columbia or in the Siskiyou Mountains, and many were set in multiple ODF Geographic Regions (per OAR 629-634-0220; Table 1, Figure 1). The remaining publication was conducted in Southeast Alaska. Twelve publications had study sites in the Oregon Coast Range, two in the western Cascades and eleven in the Interior (i.e., most of the Willamette Basin and upper Umpqua Basin). Nine studies had sites in western Washington, the majority of which were in the Coast Range (60-70% of the publications).



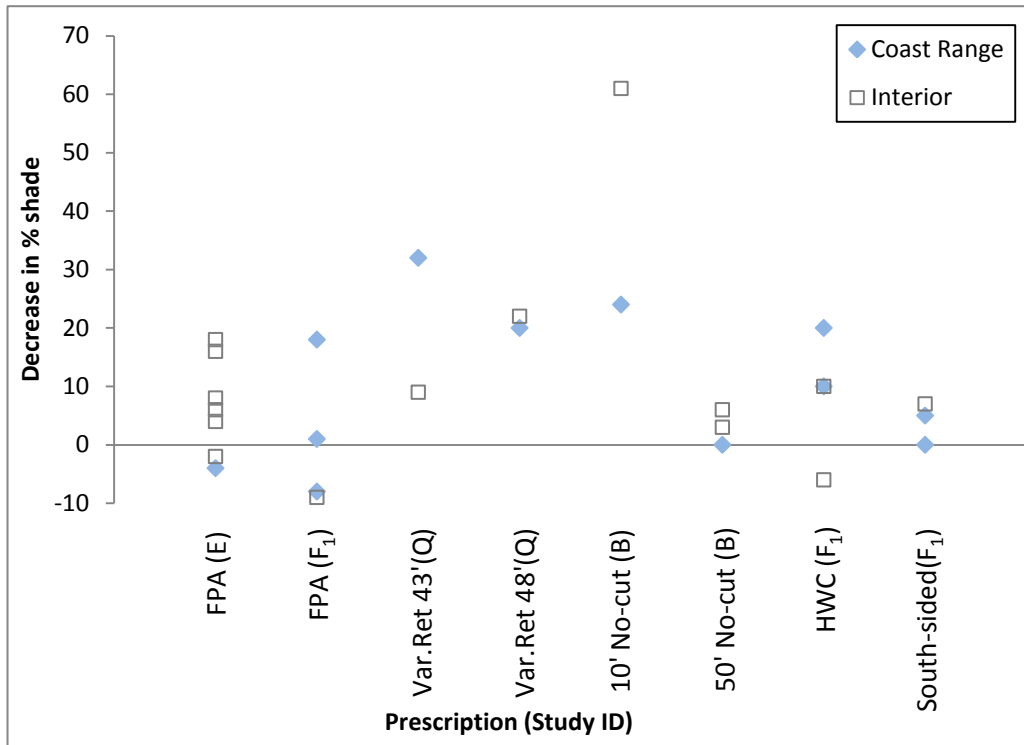
**Draft Figure 1b. Oregon Department of Forestry Geographic Regions.**

A secondary purpose of this systematic review is to inform the Board's decision on the geographic extent of the rule analysis process. Overall, most sites studied are located in the Coast Range (n=82), followed by Interior (n=47), and West Cascades (n=23; no data were found in the South Coast or Siskyou Geographic Regions). However, data are only comparable between Geographic Regions when data assess the same buffer prescription from the same study conducted in more than one Geographic Region. Thus, there are many fewer data available for

comparison (15 combinations of temperature or shade data for specific rule prescriptions and studies from different Geographic Regions; Figures 2, 3). Whereas data from publications are included in this analysis regardless of their confidence score, it is worth noting:

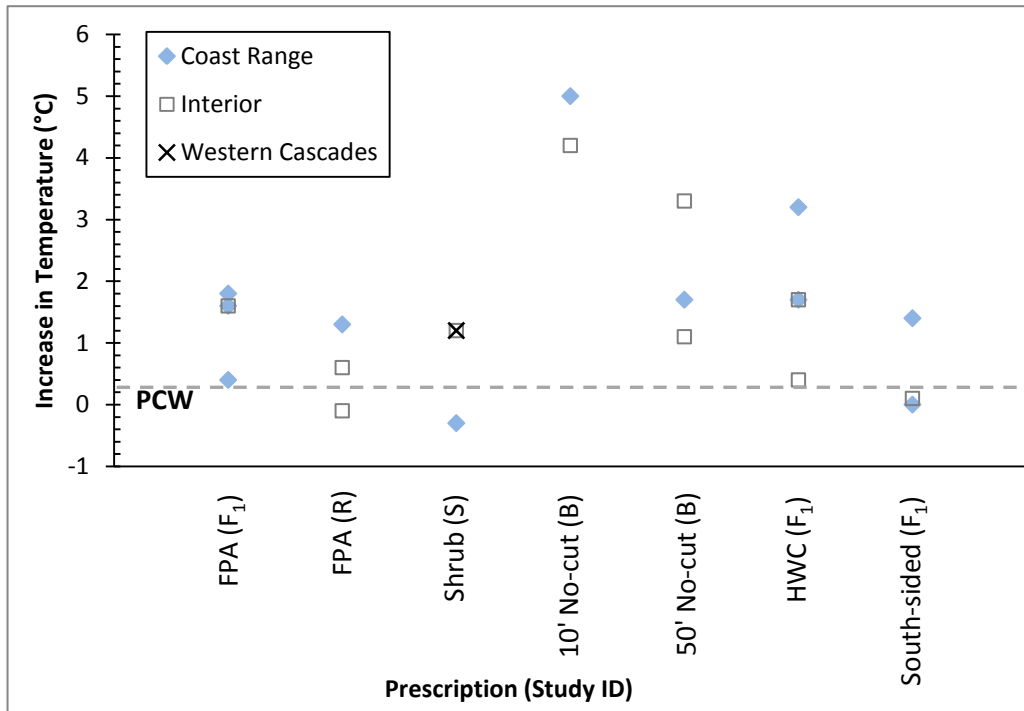
- Most comparisons are from studies with low confidence scores ( $<7$ );
- Although the Coast Range and Interior are the only Geographic Regions with sites ( $n=31$  and  $5$ , respectively) from studies with high confidence scores ( $\geq 10$ ), only two of these sites are comparable between Geographic Regions; and,
- All of the Western Cascades sites are from studies with low confidence scores, and most of these sites are not comparable with those of another Geographic Region.

To gain insight on regional differences in buffer effectiveness, changes in shade and temperature are plotted with respect to prescriptions from various studies in Figures 2 and 3, respectively (Appendix C). No clear picture emerges when comparing prescription effectiveness between Geographic Regions for any given study. This lack of clarity is partly due to insufficient data with which to make robust comparisons: no comparisons between Geographic Regions for a buffer prescription have more than two sites for each Geographic Region and study. In addition, no clear pattern presents itself by what data do exist. The Coast Range appeared to have greater change in shade or temperature with buffers in seven comparisons with those of Interior, whereas the latter appeared to have greater change in shade or temperature with buffers in four instances (Figures 2, 3). Four comparisons of these two regions appeared to have buffers with similar changes in shade or temperature. The only Western Cascades site assessed had the same impact as Interior, both of which were larger than the Coast Range (Figure 3).



**Draft Figure 2b. Decrease in shade for each Geographic Region.**

Each symbol represents data from one site for a particular rule prescription from a particular study. The symbol type denotes the ODF Geographic Region: blue diamonds are Coast Range sites, hollow squares are Interior sites. Prescriptions are: FPA = Forest Practices Act; Var.Ret = Variable Retention; 10' and 50' are for No-cut buffers of 10 and 50 feet, respectively; HWC = hardwood conversion; South-sided = buffers retained on southern side of streams. Letter in parentheses denotes study ID: E=Dent, 2001; F<sub>1</sub>=Dent and Walsh, 1997; Q= Morman, 1993; B=Brazier and Brown, 1973(Table 1).



**Draft Figure 3b. Increase in temperature for each Geographic Region.**

Each symbol represents data from one site for a particular rule prescription from a particular study. The symbol type denotes the ODF Geographic Region: blue diamonds are Coast Range sites, hollow squares are Interior sites, and “x” is a Western Cascades site. Prescriptions are: FPA = Forest Practices Act; Shrub = shrub shade; 10’ and 50’ are for No-cut buffers of 10 and 50 feet, respectively; HWC = hardwood conversion; South-sided = buffers retained on southern side of streams. Letter in parentheses denotes study ID: F<sub>1</sub>=Dent and Walsh, 1997; R=Newton and Cole, 2013a; S=Newton and Cole, 2013b; Q= Morman, 1993; B=Brazier and Brown, 1973(Table 1). The dashed line labeled PCW is the Protecting Cold Water criterion.

## Appendix E. External comments, and responses to these comments, on draft report and associated additions

This appendix documents comments from external reviewers (e.g., conservation organizations, agency personnel, industry experts) on the draft report plus its additions (Executive Summary and Geographic Ranges and Physical settings; see Appendix D), and the associated responses from both the Department and the External Scientists hired to conduct the review.

### E.1 External comments, and responses to these comments, on the draft report

Liz Cole, Senior Faculty Research Assistant, OSU/FERM

<u>Line #</u>	<u>Comment/modification</u>	<u>ODF Response</u>	<u>External Reviewer Response</u>
	Report needs to be proof read for spelling and grammatical errors. Examples, <i>macrophyllum</i> instead of <i>macrophyllum</i> , <i>menzesii</i> instead of <i>mensiezii</i> , <i>sitchenis</i> instead of <i>sitchensis</i> , “between” is for comparison of two items, use “among” for more than two items, and use “were” not “was” with data, which is the plural form of datum.	Agreed.	Thank you for catching these errors. We made edits to the document.
318-326	The authors include the importance of accuracy and resolution and indicate that it should be considered. I could not find where they reported the accuracy and resolution for the studies they extracted. (I was expecting that information in either Table 1 or Appendix B.) They also suggest that resolution is more critical for the statistics of upstream and downstream comparisons. Both accuracy and resolution need to be considered, and many scientists (myself included) often fail to address that in scientific publications. For example, accuracy of	For external reviewers to respond.	We agree with the reviewer that this is an important consideration. Due to the inconsistencies in reporting accuracy and resolution in the literature reviewed, we determined that the best way to caution readers about the results would be to call their attention to the potential error in measures in

<b><u>Line #</u></b>	<b><u>Comment/modification</u></b>	<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
	many thermistors is 0.2° C. An upstream thermistor reads 12.0° C, meaning the “true” reading lies between 11.8° and 12.2° C. A downstream thermistor reads 12.4° C, with the “true” reading between 12.2° and 12.6° C. The difference between the thermistors is 0.4° C, which exceeds the PCW, but the “true” reading of both could be 12.2° C. The accuracy of the thermistors is especially important for some of the older studies which utilized less accurate thermistors.		this section (3.3) of the review document. When reported in the publication, we included these data in Table A.6.2 of Appendix B. We removed sentence suggesting resolution being more important than accuracy for upstream/downstream comparisons as this statement is fraught with assumptions.
401	There are no sites in west Cascades, revise sentence accordingly.	No comment	Revised
433	Did Groom also report the chances of exceeding the criteria prior to harvest? If so, that should be included. If not, then that should be addressed.	Out of scope for this review.	A statement was made in the text about the exceedance results, but the information cannot be presented on the plot because values are different.
448-9	I realize that we mix English and metric measurements in regards to stream temperature rules. Are the rules for conifer stocking and snags in English or metric?	Change to all English units for this sentence (i.e., 50 trees/acre and 10-45 snags/acre)	Changed to English units.
500	There is a difference between a “shrub” buffer and a “no-tree” buffer. A no-tree buffer may or may not have shrub shade over the stream, and that may make a difference in the amount of light reaching the stream. I would suggest mentioning that distinction. Newton and Cole (2013b) reported on a no-tree buffer that lacked shrub cover in places, as indicated in the paper.	Would be good to mention difference between shrub and no-tree	We have added text to the paragraph explaining that “no-tree” does not necessarily mean “shrub”.
516	Newton and Cole did report formal statistics on the trend	Defer to external reviewers.	Text has been altered to account

<b><u>Line #</u></b>	<b><u>Comment/modification</u></b>	<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
	line comparisons		for the regression analysis.
655	Newton and Cole (2013a) also tested the one-sided (called partial) buffer. Results were confounded with those units being downstream of harvested units with significant warming after harvesting. However, on three of the four streams, there were no significant differences in daily maxima after harvesting.	Since post-harvest data for partial buffer sites are confounded due to units being downstream of other harvested units (i.e., they lack appropriate controls), it is not scientifically valid to compare post-harvest daily maxima results with those from pre-treatment.	Agreed with ODF. We chose not to include the results in the review.
843	Citation is Western Journal of Applied Forestry 2013 28(3):107-115.	No comment.	Change made.

**Josh Seeds, Nonpoint Source Pollution Analyst, ODEQ**

<b><u>Line #</u></b>	<b><u>Comment/modification</u></b>	<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
	The table of summary information is a nicely usable summary.	Agree.	Glad it is helpful
	The tabular format for comparing relevance, effects modifiers addressed, etc. , is also brilliant.	Glad it is helpful.	Thank you
	The graphs comparing BMP effectiveness with study	Glad it is helpful.	Glad they are helpful

<b><u>Line #</u></b>	<b><u>Comment/modification</u></b>	<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
	quality are extremely helpful for understanding the results of the studies, how they compare, and quality-based weighing of information.		
	Is there a way to show which buffer sizes had which effects in the studies that looked at a wide range of widths (Figures 7, 8, & 10)?	Some of the studies provide the data with which to plot this, some do not. Extracting all these data is beyond the scope of this report	Agreed with ODF.
	A table of rule alternatives, number of studies addressing each, and the support for each would be a good addition to the report. It would be a nice way to see which ideas would really be a large-scale experiment and which we already have some idea of performance and how good that performance is at meeting PCW/maintaining shade.-> table with columns such as: 1.Rule Alternative 2.# of Publications Addressing Alternative 3.Quality of Studies 4. Effectiveness of Alternative According to Pubs (1 column for shade, 1 for temp)	Completed Table A.6.4 has the first two components, Table 1 has the fourth component and it is recommended that it include the 3 <sup>rd</sup> component. However, the report's figures (1-12) show this information, and thus such a table is not warranted.	Agreed with ODF. Information is being supplied in other tables.

**Maryanne Reiter, Hydrologist, Weyerhaeuser Co.**

<b><u>Line #</u></b>	<b><u>Comment/modification</u></b>	<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
3	The first line of the introduction focuses the report on	No comment.	Added intro sentence

<u>Line #</u>	<u>Comment/modification</u>	<u>ODF Response</u>	<u>External Reviewer Response</u>
	salmonids and temperature. Consider a broader introduction about how stream temperature plays a key role in structuring the composition of biotic communities in aquatic ecosystems and how it also influences the rate of chemical processes (DO, etc.). Then let the audience know that this report is specifically on temperature and salmonids because that is what the DEQ standards address.		conveying these points.
7-11	This paragraph describing thermal regimes could be strengthened. I would indicate that a stream's thermal regime results from daily and seasonal variations in the rate of thermal energy transfer between a stream and its environment. As the paragraph is written (e.g., line 8) it implies that thermal energy transfer is one way. Also note that they use the term 'heat' when indicating thermal energy. Heat is the transfer of thermal energy between 2 objects of different temperatures.	-line 8: add "to and" before "from" -Physicists refer to the flow or transfer of heat (P.A. Tipler, 1982, <u>Physics</u> , p.493), so fine as is, or could replace with "thermal energy".	Changed language to account for more general transfer of energy between the stream and its environment as suggest.  Changed heat to thermal energy.
12-13	Note that maintaining shade as an effective tool for minimizing stream temperature during the summer applies to certain sized streams where localized stream temperature patterns can be influenced by the near-stream environment, especially where vegetative canopies are able to substantially shade the stream. For larger streams/rivers, shading is not an effective of a tool in controlling maximum stream temperatures.	While this may be true, the part about large rivers is not germane to this review, which focuses only on small and medium streams.	This is a good point and is discussed later in the paper.
27	This line indicates that the streams the PCW target are those that are "currently cold enough to protect fish". Suggest something more reflective of the target of the PCW, i.e., prevent anthropogenic temperature increases	Agree	Agreed. We revised the text.

<u>Line #</u>	<u>Comment/modification</u>	<u>ODF Response</u>	<u>External Reviewer Response</u>
	for streams containing salmon.		
353	When the authors use the term “riparian reserve” I immediately think of a federal definition. Is there a better term for riparian areas that do not invoke a federal perspective?	Use either “riparian buffer” or “riparian management area”	We changed it to riparian management area.

### **Jeff Light, Hydrologist, Plum Creek Timber Company**

Overall, I believe this was a thorough and objective effort to find published scientific information that is relevant to analysis of the rule alternatives. I only have one edit to suggest: On page 22, line 432, the Draft SR authors state that Groom (2013; in prep) reported “...7 out of 18 sites exceeded the 16 or 18C criteria for salmonids.” This is in a sentence discussing FPA rule effectiveness for achieving temperature standards. I checked the reviewer summary of this publication (page 98 of the Draft SR), and found that only 2 sites that exceeded numeric criteria might be associated with harvest. Please verify this and revise accordingly.

<u>ODF Response</u>	<u>External Reviewer Response</u>
A more accurate portrayal: “The percent chance of a site managed using FPA rules exceeding the PCW rule was 40% and 7 out of 18 sites (four of which exhibited a potential harvest signal) exceeded the 16 or 18 °C criteria for salmonids.	Text has been altered to provide clearer details.

### **Greg Haller, Conservation Director, Pacific Rivers Council**

#### **General Comments**

While we recognize that direct solar input is the primary driver of water temperature, it is not the only factor. Stream temperature is not simply a result of shade. Rather, it is a result of interplay between numerous factors, including composition of the streambed substrate and the length of time surface water flows through it, the influence of groundwater, elevation and stand-type. Many of these

factors may be influenced by changes in management, but many may not. Without an understanding of these factors, understanding the relationships involved in water temperature may prove elusive. Advantageous management and policy is nearly impossible to realize without fully understanding the relationships. We urge the investigation team to broaden the scope of their review to include these additional factors. Only after considering all pertinent factors can prudent decisions about riparian buffers occur.

Compared to Washington forest practices, the riparian buffer regulations in Oregon Forest Practices Act are far weaker, as evidenced by the poor condition of many of the streams and rivers flowing through private forestlands in Oregon and the presence of ESA-listed Coho salmon. As such, we are very concerned about any proposal that would further weaken requirements for riparian buffers. On the other hand, we welcome discussion about how to strengthen riparian buffer requirements and this investigation provides valuable insight into the possible effects of any alteration to the existing buffer regime.

With that said, we would like to reiterate our thanks to those that helped make this investigation a reality. Attached are our specific comments regarding this review. We urge the investigation team to incorporate these suggestions into the review so that the final edition is as thorough and scientifically sound as possible.

<u>Line #</u>	<u>Comment/modification</u>	<u>ODF Response</u>	<u>External Reviewer Response</u>
167 – 173; 229 - 231	<p><b>Reviewers should more thoroughly vet possible studies prior to including or excluding them in this investigation. Reading the abstracts to determine suitability would benefit the study.</b></p> <p>The protocol for systematic review (section 2.1) states that reviewers “rigorously screened” studies for quality and relevance to the question the study sought to answer. However, reviewers based their decision to include or exclude a study based initially on the title and, only if uncertainty remained, did they investigate the abstract or read the section of the full text. The report states, “approximately 80% were rejected by reading the title.” Reading the titles alone does not ensure rigorous screening. Reviewers should more thoroughly investigate possible studies for inclusion to ensure that no relevant information is omitted. At the very least, the abstracts should be read to ensure relevant studies are included.</p>	<p>Since the search was very wide (i.e., 1,456 publications), titles of numerous publications were found that were obviously not relevant (e.g., they were in a different geography, or they were on a subject not at all related to forestry and riparian buffers). In addition, the list of all included and excluded studies was sent on March 18, 2013 to all stakeholders (including Greg Haller) for their input as to whether or not we either mis-applied the inclusion criteria, or missed a publication.</p>	<p>Though we were not included in this part of the review, we understand the necessity of ODF screening protocol.</p>

<u>Line #</u>	<u>Comment/modification</u>	<u>ODF Response</u>	<u>External Reviewer Response</u>
291 - 295	<p><b>Including studies from other regions would benefit the review and supplement the findings.</b></p> <p>Within the Western Oregon forests, there are smaller regions and forest stands with differing characteristics. Eastern Oregon forests may better represent some of these stands. Studies of inland forests should not have been automatically eliminated from the investigation.</p>	ODF staff decided that the unique combination of hydrology, latitude, and vegetation in W. Oregon limit relevance of studies from other regions to effectiveness of riparian management in forestry settings of W. Oregon.	Though the regional scope is too limited to provide guidance to other parts of the state, the review should be highly relevant to the western Oregon region.
303 - 307 354 – 356 592 - 600	<p><b>Considering other factors would contribute to a more thorough and possibly accurate investigation.</b></p> <p>The investigation on page 17 only looked at two factors: shade and temperature. However, temperature is not simply a function of shade. Numerous other factors that impact stream temperature should have been considered, including substrate composition, stand-type and the influence of groundwater.</p> <p>Other studies identified factors that play an integral role in determining the stream temperature. Those factors should have been considered more consistently throughout the investigation. Temperature is a result of interplay between numerous factors, not simply shade. While it is very difficult to fully evaluate the impact of so</p>	ODF agrees that other factors (including those listed by Mr. Haller) affect stream temperature. However, the main purpose of this review was to test outcomes for temperature associated with shade. To fully address effects modifiers is beyond the scope of this document.	<p>We clarify why the scope was limited in the introduction (see Reiter comment for line 3 and corresponding response). We also include more information about other causes of high stream temperature (see Frissell #2).</p> <p>Additionally, while applying process-based understanding is important to developing management policies, this is not the stage at which such additional analysis would be fruitful. We encourage and expect that ODF will evaluate the short-list of alternatives with respect to known</p>

<u>Line #</u>	<u>Comment/modification</u>	<u>ODF Response</u>	<u>External Reviewer Response</u>
	many variables, they should at least be considered and possibly discussed. These factors have the possibility of drastically influencing the findings, making them valuable to include.		temperature-driving processes when that time comes.
466 - 469	<p><b>The factors not discussed in other studies should be mentioned.</b></p> <p>The Groom et al, 2011 study discussed an array of other factors, which could have a large impact on the findings. The lack of these other factors in the other studies should be mentioned at least briefly to make clear if there were any circumstances that could possible alter the outcome that were not discussed.</p>	For external reviewers to respond.	The circumstances that could alter the outcome would be unique for each study and there are a large number of potential effects modifiers. To speculate on that for each study would be too cumbersome for this review. If there was something obvious of note, it is captured in the A.6.2 tables that provide information for each study and were likely incorporated into the main body of this review.

<u>Line #</u>	<u>Comment/modification</u>	<u>ODF Response</u>	<u>External Reviewer Response</u>
327 - 334	<p><b>More emphasis should have been placed on identifying studies that relied upon hemispherical photography.</b></p> <p>Seven studies relied upon densitometers to determine overhead canopy cover. These tools are notorious for their inaccuracy and their tendency for bias. Relying upon less subjective means for quantifying canopy cover would be ideal.</p> <p>While PRC recognizes that densitometers are a common method of measuring canopy closure, a concerted effort to locate studies using other means would be beneficial. While this may prove difficult, it would greatly strengthen the reliability of the findings.</p>	<p>While this type of photography may be more accurate than densitometers, we decided to include all publications that met all the minimum requirements. Had there been numerous studies that used hemispherical photography, they would have played a more prominent role in this review. However, they did not exist in sufficient numbers to warrant excluding data collected with densitometers.</p>	<p>Agree with ODF comment.</p>

<u>Line #</u>	<u>Comment/modification</u>	<u>ODF Response</u>	<u>External Reviewer Response</u>
379 - 380	<p><b>The lack of control group needs to be addressed regarding the reliability of the findings.</b></p> <p>At least three studies did not have a control group. The reliability of the findings of those studies is suspect when there is not a control group to compare against the findings. The lack of control groups and the unreliability of other control groups could drastically influence the findings, potentially making these studies far less trustworthy.</p> <p>In addition, using the pre-treatment site as a control may bias the results. The pre-treatment areas may have been previously degraded by human activities, influencing the shade and temperature data.</p> <p>Information regarding the pre-treatment area is necessary to evaluate the findings of those studies. Without a comprehensive understanding of the properties of the pre-treatment sites, it is not possible to understand the results of the treatments.</p>	<p>The sentence needs to be re-worded since these studies did have controls (or they would not have been included in the study; in fact, a different publication was originally included, but later excluded due to lack of control).</p> <p>The scope of this review considers how interventions affect the existing shade and temperature regime, not historic temperature or shade ranges.</p>	<p>The sentence has been adjusted to clarify circumstances where statistical analyses were not conducted.</p>
374 - 376	<p><b>Autocorrelation of temperature time series data for all the studies would be very beneficial.</b></p> <p>This information would allow for higher statistical robustness, strengthening the findings and making this a more reliable</p>	<p>While autocorrelation of temperature time series data provides more robust findings, to exclude studies because they lack this autocorrelation would potentially exclude evidence that still has value, especially given there are so few studies that were</p>	<p>Agree with reviewer, though this cannot be done because requiring autocorrelation would dramatically reduce the number of studies available for review.</p>

<u>Line #</u>	<u>Comment/modification</u>	<u>ODF Response</u>	<u>External Reviewer Response</u>
	review.	included.	
385 - 386	<p><b>The nine alternatives lacking a highly relevant study should be addressed.</b></p> <p>While those nine alternatives lacked a highly relevant study, a brief discussion of them would strengthen the study. It would be very beneficial to give the reader at least some cursory knowledge regarding those alternatives so people know what options did not have any scientific basis.</p> <p>Also, very little background was provided regarding the specifics of each alternative. Understanding what each alternative entails is essential to comprehending the study's findings. Thus, the study should discuss the logistics of each option prior to delving into the findings.</p>	Text can refer to Table A.6.4 for readers that want to know which rule alternatives were not included, and Table A.6.1 defines every rule alternative. It would be good to add a sentence at the beginning of each sub-section in Section 3.5 to ensure the reader understands clearly the alternative considered.	A sentence was added to the beginning of each sub-section in Section 3.5 to help describe the rule alternatives. We have also added a list of rule alternatives that did not have highly relevant studies to the intro to Section 3.5.
398 - 400	<p><b>It should be made clear which studies only had harvest on one side of the waterway compared to the studies that had harvest on both sides.</b></p> <p>Having harvest on one side of the stream has the possibility of biasing the results. The investigation should clarify whether study areas had one or both sides harvested. Discussing the possible impact on the results of those studies would provide insight into the results. The</p>	For external reviewers to respond.	While this might increase clarity concerning the outcomes measured, adding the clarification would be difficult because some studies do not report it, some report it but not which side of the stream and/or stream orientation, and thus drawing conclusions is beyond the scope of this report.

<u>Line #</u>	<u>Comment/modification</u>	<u>ODF Response</u>	<u>External Reviewer Response</u>
	possible inconsistency in the findings due to this factor is highly relevant and deserves some discussion.		
410 - 412	<p><b>It is very important to have large sample sizes and consider differences in shade less than 0.5% inconclusive.</b></p> <p>The investigation team is correct that larger sample sizes are very important. They help to mitigate some of the factors that can bias the results. Considering the unreliability of the densitometers, it is good to consider slight changes in shade inconclusive.</p>	Agree	Agree
425 - 426	<p><b>Discussion of the reasoning for the confidence scores is needed.</b></p> <p>The confidence scores of these studies is a highly relevant factor. Understanding why some studies had high scores and why other had low scores would be very useful for understanding the studies and findings as a whole. While the study briefly mentioned the confidence scores, the basis for of these figures is worth discussing.</p>	Agree, add to discussion the why and what of the figures in a paragraph following line 391.	Agree that confidence scores need to be thoroughly explained. They are explained in section 2.7 and now in a footnote with the first of the results figures.
450 - 453	<p><b>Discussing the pre-harvest and post-harvest conditions would benefit the investigation.</b></p> <p>There was no detectable change in the shade conditions. However, there was between 80-95% shade coverage to begin</p>	For external reviewers to respond.	Description of the site conditions can be found in Tables A.6.2. for speculation to other types of stream conditions.

<u>Line #</u>	<u>Comment/modification</u>	<u>ODF Response</u>	<u>External Reviewer Response</u>
	with. While this study may be sound, it is worthwhile to discuss the stand conditions before and after treatment, as this type of management on other streams may have a greater impact if there was less shade before treatment.		
462 - 463	<p><b>The change in temperature should be discussed in more detail.</b></p> <p>The change in temperature was quoted to be zero degrees yet there was a range of - 0.9 to +2.5° C. This range is quite large, justifying a more in-depth explanation. If it were a matter of statistical relevance, stating such would benefit the study's results.</p>	Discussing the range of variation, and the cause of it, for every study included in this review is beyond the scope of the review.	Agree with ODF. For discussion of each individual study, see A.6.2. tables.
498 - 499	<p><b>A plan for accruing additional data should be created.</b></p> <p>The investigators did a great job at identifying the need for additional data on this topic. We strongly agree with that conclusion. As such, we would urge the accumulation of additional evidence to answer the remaining questions on this topic.</p>	Outside the scope of the Systematic Review but will be retained for future use in the pending Monitoring Strategy update.	Agree with ODF
597 - 600	<p><b>The results from studies in extreme headwater reaches of streams must not be considered highly relevant.</b></p> <p>The extreme headwaters are much more</p>	While “extreme headwaters” likely exhibit more variable stream temperature regimes, we decided that drawing a line between these reaches and those downstream could	Agree with reviewer comment, but as described by ODF, it was too challenging to determine which studies fell

<u>Line #</u>	<u>Comment/modification</u>	<u>ODF Response</u>	<u>External Reviewer Response</u>
	variable in their temperatures. As such, those results are likely far more biased because of other unreported factors. These stream reaches are not highly relevant due to the possible bias in the results. While these results should be included, too much reliance on them is detrimental to the results.	not be done consistently-, and defensibly-, enough for this review. Namely, sufficient information is not consistently provided within study descriptions to classify the streams in question according to ODF regulatory standards.	into that category. The referenced sentence points out this variability and the caution for interpretation is implied.
614 - 616	<b>More research is needed to test this finding.</b> The “most effective” buffer still resulted in a decrease in the canopy density. Moreover, it had a lower confidence score than other studies. Due to the lack of confidence, reliance on this study is misplaced.	Outside the scope of the Systematic Review but will be retained for future use in the pending Monitoring Strategy update.	We agree. An important goal of this work was to identify the remaining gaps in knowledge. The text does not suggest disproportionate reliance on this study and states clearly that the confidence for the study is low.
711 - 720	<b>Identification of additional studies for inclusion is needed.</b> While we understand the difficulty in identifying and characterizing studies for inclusion, additional studies would be extremely beneficial to increase the confidence in these findings. Studies addressing all alternatives would be ideal. More information in general would strengthen the investigation greatly.	While including more studies could be helpful, we still need to include only studies that help answer the review question. Part of the purpose for this review is to uncover what we don’t know.	We agree with ODF. An important goal of this work was to identify the remaining gaps in knowledge.



**Chris Frissell, Ph.D., Consulting Research Ecologist and Freshwater Conservation Biologist for Mary Scurlock, Policy Analyst, M. Scurlock and Associates**

**1. Introduction**

In general this is a well-executed and well-written report that clearly describes and directly responds to a specific charge from the Oregon Department of Forestry and the Oregon Board of Forestry. It's good to see a highly professional and transparent approach taken to literature review. On the other hand, the results do highlight inherent limits of the Systematic Review framework that reduce the scope for inference and useful interpretation of available research.

In the following comments I identify a handful of issues that could be more clearly addressed in the report and constitute potential limitations of the approach. However, in my view these shortcomings are inherent in the research question posed and in the available science, with further constraints imposed by the Systematic Review framework. That is, resolving these could somewhat improve the veracity of this report, but will likely not substantively change its conclusions and implications.

The most important conclusion of this report should not be lost on its agency sponsors: *for the vast majority of the 16 alternative riparian management approaches identified by the Board of Forestry, existing empirical science is adequate to address only a small handful of them*, namely those for which some equivalent measures have been implemented on the ground by way of past state and federal rules. On its face the "Systematic Review" method is profoundly unsuited to address the potential outcomes of newly proposed management schemes, because few or no empirical studies have tested the specific treatments called for. Secondly, for the handful of riparian management approaches for which the "SR" method is suited at all, *the results rest on a very small number of studies were conducted with adequate methods and designs*.

<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
Agree that most of the rule alternatives have few-to-no studies that address them.	Agree
The purpose of this SR is to see what science exists with which to assess the effectiveness of proposed rule alternatives, which the review accomplishes. ODF agrees that this information needs to be bolstered by additional analyses to address the potential	Though the SR method has its limitations, the goal is to find a way to narrow down the scope of information quickly and effectively in a resource-friendly manner. Ideally, funding would be available to conduct a broader, more inclusive review, but we

<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
outcomes of proposed rule alternatives; these analyses will be conducted outside this review.	believe the SR method is a reliable and strong substitute for the more labor-intensive efforts.

Somewhat less problematic but still limiting is the third lesson: even among the few studies that meet these requirements, researchers reported different methods and metrics, so that the equivalency of results is conditional and the ability to draw inferences is further narrowed. The authors of this report have done a thoughtful job of respecting this condition, while not allowing it to unduly limit inference.

<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
ODF agrees that research methods and metrics differed between studies, and that Drs. Czarnomski and Hale did a thoughtful job of respecting these differences.	Thank you.

## **2. Problem of Equivalency of Changes in Shade and Water Temperature**

A conceptual premise underlying this report is that shade and stream temperature are directly related, and that canopy shade from riparian vegetation is the primary determinant of maximum stream temperatures. This presumption does not originate in the report itself, but in the conception of the questions the report was commissioned to address. The authors have taken care to avoid embracing this premise outright as an analytic matter in two ways: 1) canopy shade and stream temperature are treated separately as response variables, that is, in parallel analyses, and 2) “effects modifiers” are considered as covariates, to the extent this is possible with available data from the sources studies.

Considerable attention has been paid in the scientific literature to the point that shade reduction is not the only means by which logging can alter stream temperature. In addition to changes in channel structure, sediment conditions, and streambank erosion and reduced vegetative stability following logging, canopy reduction across a watershed or catchment surface can affect shallow groundwater thermal regimes. Pollock et al. (2009) found that post-logging temperature increases in Washington streams corresponded to catchment-wide extent of recent logging more strongly than to extent of logging or canopy reduction in riparian areas that would directly affect stream surface shade (See also Moore et al. 2005). Pollock et al. (2009) suggest that landslides and debris

flow-induced changes to channel conditions (namely, reduced hyporheic interchange and flow storage), as well as groundwater warming may explain logging-related stream warming. Bourque and Pomeroy (2001) reported a similar correlation with catchment-wide extent of logging in New Brunswick, such that stream warming was unrelated to riparian forested buffer width. Janisch et al. (2012) reported that small headwater streams in logged catchments warmed more if they drained a larger area of wetlands. More extensive wetlands would likely correspond to more extensive areas of near-surface groundwater, as well as open water surface, within these catchments.

In several of the above studies, a major causal mechanism for stream warming appears to have been the warming of near-surface groundwater in response to logging and subsequent soil warming with catchment-wide canopy reduction. While Janisch et al. (2012) pointed out that post-logging catchments may release more groundwater to streams because evapotranspiration is reduced, the temperature of shallow groundwater (2.5 m or less from the soil surface) can increase with soil warming under open land cover conditions in summer (Pluhowski and Kantrowitz 1963, Hewlett and Fortson 1982, Glazik 1987, and other sources cited in Rhodes et al. 1994). Therefore, under certain landscape conditions, logging could increase upland groundwater elevations and expose more near-surface groundwater to warming, at the same time it exposes the soils to greater warming because of canopy loss. The result is likely to be increased discharge of warmer water to streams in spring and summer months as a common result of catchment-wide logging. This may or may not be masked by larger fluxes in daily maximum surface stream temperature that are more directly influenced by riparian canopy condition, although groundwater warming should still be evident as increased daily minimum and median stream temperature. Surface temperature of small streams in the Oregon Cascades recovered about 15 years after logging of their catchments (Johnson and Jones 2000); this corresponds with the time commonly needed for regeneration of canopy shade along small channels in western Oregon, but also for canopy recovery over upland soils, hence the presumed return of extensive vegetative thermal buffering of soil and shallow groundwater. Roads may also intercept and divert groundwater to surface and near surface flow paths where it is more vulnerable to heating before it is delivered to streams (Gucinski et al. 2001).

Landforms and soils in the catchment likely determine the vulnerability of groundwater to warming following canopy reduction. In very steep and highly dissected terrain, especially where soils are well-drained and slope-bench wetlands absent, very little near-surface groundwater may be present for a long enough residence time to experience post-logging warming. In moderately sloping, gently sloping, and wetland-rich terrain, extensive near-surface groundwater is present within the soil depths where it is vulnerable to

warming, and the spatial and temporal duration of vulnerability may increase as a result of post-logging reductions in evapotranspiration.

***From a regulatory viewpoint, the important take-home message of these observations is that regulating canopy shade cannot be presumed sufficient to protect all streams from logging-related summer temperature increases.*** This point contradicts a basic premise of this Systematic Review, and is not illuminated or disclosed by the review because 1) studies demonstrating the effects were deemed of inappropriate design for further consideration *a priori*, and 2) for the studies included, the analysis assumes that stream temperatures in “control” streams, where riparian areas were not logged, represent baseline conditions, whether their temperatures increased, decreased, or remained stable during the study interval. In fact, groundwater-mediate warming of control streams could bias the observed effect of riparian logging on canopy-mediated stream temperature downward, because the study baseline also warms.

<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
It is inaccurate to state the studies demonstrating watershed-wide effects were deemed inappropriate <i>a priori</i> . For example, had Pollock et al. (2009) provided data collected within 5 years of harvest (instead of binning into <20 years since harvest), their publication would have been included in this review. The reason 5 years was chosen as a cutoff is to provide a conservative timeframe in which to measure impacts of harvest on stream temperature before shade from vegetation growth recovers to nearly the same as that pre-harvest (Hale, 2007; Johnson and Jones, 2000).	It is important to recognize that this review question is purposefully limited in scope and that does place boundaries on use of conclusions from this report. You provided a helpful literature review and we have incorporated a few sentences describing the limitations in the introduction and in section 3.3. We also included more effects modifiers regarding site history.

From an analytic point of view, this problem could be checked by a more thorough review of catchment conditions of the study streams, including changes caused by logging, roads, fire, or other extensive disturbances within 15 years prior to and during the interval of the temperature study cases. In particular the conditions in control stream catchments are of concern, but also it is important that catchment conditions in treatment streams be similar to the controls within the 15-20 year period prior to the onset of the experimental study. Ideally they should all be free of extensive canopy and vegetative, or hydrologic perturbations within the two

decades prior to the study, but where such events have occurred, then they should be evenly distributed amongst control and treatment catchments. A retroactive, but only partial, means of analytically accounting for any known differences would be to include catchment history variables in the analysis of “effects modifiers.”

*Additional Analysis Needed.* The question of how closely shade relates to stream temperature is briefly and qualitatively considered in the report in the context of the few studies considered that measured both factors in the field. I would suggest the authors consider a formal analysis of this question by extracting the data from each study in this report that reported both change in shade and change in temperature following logging treatments, aggregate the data and quantitatively evaluate their correlation. If change in shade and change in temperature are reasonably well-correlated across the studies, then focusing stream protection policy on riparian shade may be a useful approach. If not, then a more robust policy approach to stream thermal protection is called for. As other researchers have pointed out in prior studies, residuals around the shade v. temperature relation could be usefully examined against covariates (“effects modifiers”) to help assess what other ecosystem features play a role in keeping water cool, and therefore require protection (such as base flow, see Arismendi et al. 2012, 2013).

<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
Extracting all the shade and temperature data from studies with both datasets is beyond the scope of this report.	We agree that the review question would be better answered with such an approach; however, this effort is outside of the scope of this report. An important goal of this work was to identify the remaining gaps in knowledge and there may be some merit to additional data analysis in future stages of the Rule Analysis.
Change in shade and change in temperature have been well-correlated across studies previously (Groom et al., 2011; Holtby and Newcombe, 1982; Johnson and Jones, 2000; Johnson, 2004), and thus we did not undertake this correlation.	See above

### **3. Assumption that Shade and Temperature are Not Equivalent only for Eastern Oregon**

Given the global presumption that shade and stream temperature are equivalent and correlated metrics, as discussed above, it is not readily apparent as a scientific matter why studies from eastern Oregon, or any other region of forested, coldwater streams, were

excluded from the set of studies to be considered for this report. Unless other hydrologic, geomorphic, or high-resolution vegetative or microclimatic factors are critical to determining stream thermal regimes relative to canopy shade, then studies from forested mountain regions of eastern Oregon, Eastern Washington, and northern California should be useful to include in the scope. If the so-called “effects modifiers” are so different for these regions that stream thermal dynamics are fundamentally different, this should be demonstrable through specific data or analysis. We know that covariates of stream thermal regime vary widely within streams and within regions, hence it appears most likely the context of “effects modifiers” is a complex and overlapping functional domain that spans all of the regions.

<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
The Board of Forestry declared a finding of degradation based on a study of 33 sites in western Oregon. In addition, they limited the rule analysis (i.e., the basis for this SR) to western Oregon, and agreed to only include studies located in forests similar (i.e., with similar hydrology, vegetation characteristics, and latitude) to western Oregon.	No additional comment

#### **4. Simplification of “Effects Modifiers”**

The complex and systemic problem of covariate causal factors determining stream thermal regime is considered in this report in terms of “effects modifiers,” at least where some data are available in the studies deemed to be in scope. However, it is already well-established that such covariates can have large quantitative and qualitative influence over how streams respond to changes in canopy shade or other single factors (e.g., Arismendi et al. 2013). Therefore, I remain concerned that the results presented in this report could misrepresent reality if “effects modifiers” are not given more systematic and exhaustive treatment. For example, if because of undocumented reasons of geomorphology or groundwater hydrology a “control” stream is more sensitive to climate forcing than neighboring streams used as “treatments” in a riparian logging study, then the control’s greater sensitivity could result in overestimation of baseline temperatures and underestimation of potential effects of canopy shade if post-treatment years are warmer and sunnier. Conversely, treatment streams that are thermally buffered by unexamined geohydrologic factors will show less response to canopy reduction than would other streams, or in some cases may actually cool post-logging if groundwater discharge and baseflow increases result from extensive vegetation reduction in the catchment.

There is no easy solution to this problem, particularly when relying on past studies that unevenly documented or failed to consider geohydrologic and other variation among study streams. In the future, different study designs, such as designs that measure how downstream thermal profiles vary in response to changes in riparian vegetation, or what percentage of a stream length exceeds some maximum temperature threshold, and larger sample sizes are likely to shed more light on the question of thermal impacts and sensitivity. Moreover, better tracking of upland treatments is needed in logging studies-- not just consideration of whether riparian zones were wide or narrow, thinned or unthinned, continuous or patchy, but also the logging alteration of upland areas, including total catchment area logged over time, and proportion of wetland area logged

*Implications of scientific limitations for policy: Need to tier the limits of response to effectively protect stream resources.* Meanwhile, we are stuck with studies that do not adequately account for this complexity, and forced to draw what inference we can to inform policy. But recognizing these scientific limitations is vital to framing policy in a way that will actually result in resource protection. There are many reasons why a riparian logging treatment in stream A might have a lesser, or a greater effect, in stream B. Until we have sufficient scientific understanding and field information to explain those reasons and classify streams reliably in terms of their probable response, the only way to assure resource protection will be to assume all streams could behave like the most sensitive streams in the record. For this reason, I suggest this problem is best suited to an analytic approach such as quantile regression (e.g., Bryce et al. 2010), which emphasizes the limits of response, rather than the mean response to an independent or treatment variable. Embracing this kind of approach, whether nested within the Systematic Review context or another, could much more effectively advise policymakers on what steps are needed to effectively achieve resource protection on a regional or state-wide basis.

<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
The Board of Forestry will have to determine the degree of certainty to use if they choose to modify the riparian rule.	The unique conditions for each study and large number of potential effects modifiers that are not necessarily explained in the original paper make it too cumbersome to speculate on that for each in this review. If there was something obvious of note, it is captured in the A.6.2 tables that provide information for each study and were likely incorporated into the main body of this review. We agree that the method for modifying the riparian rule needs to take into account the uncertainty and unknowns.

## 5. Hazards of Data Extraction Apart from Authors' Knowledge

One endemic risk with the SR method, or any other means of meta-analysis, is that the specific limits of data could be compromised when data are “lifted” from the original published source and applied in a somewhat different analytic context. This concern is acknowledged in the report, and as far as I can discern the authors have done a conscientious and careful job of respecting the limitations of each study design and data set. This is less difficult in this instance because only a small number of studies provided the data for the vast majority of the analysis.

## 6. Absence of Studies Directly Relevant to Many Alternatives

The fundamental shortcoming and fact of life disclosed by this report is that existing field research is largely unsuited for addressing the vast majority of the management alternatives under consideration by the Board. While it did not take a study to determine this, hopefully this result will underscore that *an entirely different approach will be necessary to assess potential environmental effects of unstudied riparian treatments.*

<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
This SR is designed to answer questions relating to assessing effectiveness of riparian buffer prescriptions that have been tested in the western Pacific Northwest. It was not designed to exhaustively explore new buffer alternatives but to understand the scientific underpinnings of the proposed alternatives scoped with input from stakeholders as directed by statute for the rule analysis process. The Board made a decision in July 2012 that the range provided by the 16 alternatives being considered was acceptable.	We agree that the Board will have to have a different approach for decision-making where there is no available information on the effects of a particular rule alternative.

In the past, simulation modeling using heat budget and related models has been used to compare stream thermal outcomes under different management scenarios. One potential value of the present report is that that vetted data from the studies reported here could provide the empirical basis for calibrating a stream temperature simulation model. If the model proves robust to the studies reviewed here, and simulates their outcomes with acceptable precision, then it could be turned to evaluating some of the other riparian management alternatives proposed by the Board.

<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
The SR was not designed to provide a single answer of which rule alternative is best (in fact, the protocol explicitly states that no recommendation will be made of which alternative to select). Instead, the SR was designed to provide information on the current state of knowledge of the effectiveness of various riparian management strategies. Additional analysis will likely be necessary to fully flesh-out rule alternatives.	An important goal of this work was to identify the remaining gaps in knowledge. This seems like an appropriate topic for new research.

While a stepwise improvement over past modeling that has often been weakly grounded in empirical data, this modeling approach is not without problems and risks because it assumes stationarity (Milly et al. 2008) and uniformity of groundwater, surface water, and canopy shade effects even though various treatments may in fact affect these factors and their relationships differently. For example, a south-side-retention only alternative might retain a significant fraction of shade over the stream channel, but expose a large area of riparian area and associated wetlands to increased solar insolation, affecting near-surface groundwater temperatures.

## 7. Conclusions

In sum, from a policy point of view the limitations of the available research present two fundamental alternatives if the Board is to ensure that its rulemaking has a rational scientific basis:

- it will have to settle on *fewer potential alternative management strategies* and invest substantially greater resources in carefully designed and executed scientific field tests of outcomes of implementing them in the field;
- it must *adopt a conservative protection strategy* that ensures resource conditions are maintained or improving for even the most sensitive waters.

<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
Outside the scope of the Systematic Review but will be retained for future use in the pending Monitoring Strategy update	Agree with ODF

## Literature Cited

Arismendi, I., S.L. Johnson, J.B. Dunham, and R.Haggerty. 2013. Descriptors of natural thermal regimes in streams and their responsiveness to change in the Pacific Northwest of North America. *Freshwater Biology* 58:880-894. doi:10.1111/fwb.12094

Arismendi, I., S.L. Johnson, J.B. Dunham, R.Haggerty, and D. Hockman-Wert. 2012. The paradox of cooling streams in a warming world: Regional climate trends do not parallel variable local trends in stream temperature in the Pacific continental United States. *Geophysical Research Letters* 39, L10401, , doi:10.1029/2012GL051448. [online] URL:

<http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/36506/ArismendiIvanCEOASParadoxCoolingStreams.pdf?sequence=1>

Bourque, C.P.A., and J.H. Pomeroy. 2001. Effects of forest harvesting on summer stream temperatures in New Brunswick, Canada: An inter-catchment, multiple-year comparison. *Hydrology and Earth System Sciences* 5(4):599-613.

Bryce, S.A., G.R. Lomnický, and P.R. Kauffmann. 2010. Protecting sediment-sensitive aquatic species in mountain streams through the application of biologically based streambed sediment criteria. *Journal of the North American Benthological Society* 29(2):657–672. DOI: 10.1899/09-061.1

Glazik, R. 1987. Dynamics of shallow groundwater temperature in the Vistula abandoned valley, the Plock Basin. *Geographica Polonica* 53:115-128.

[http://rcin.org.pl/igipz/Content/4204/WA51\\_13403\\_r1988-t53\\_Geogr-Polonica.pdf#page=121](http://rcin.org.pl/igipz/Content/4204/WA51_13403_r1988-t53_Geogr-Polonica.pdf#page=121)

Gucinski, H., M. J. Furniss, R. R. Ziemer, and M. H. Brookes. 2001. Forest roads: a synthesis of scientific information. Gen. Tech. Rep. PNWGTR-509. U.S.

Department of Agriculture, Forest Service, Pacific Northwest Research

Station, Portland, OR.

Janisch, J.E, S.M. Wondzell, and W.J. Ehninger. 2012. Headwater stream temperature: Interpreting response after logging, with and without riparian buffers, Washington, USA. *Forest Ecology and Management* 270:302-313.

Johnson, S.L. and J. A. Jones. 2000. Stream temperature responses to forest harvest and debris flows in western Cascades, Oregon. *Canadian Journal of Fisheries and Aquatic Sciences* 57(Suppl. 2):30–39

Hewlett, J. D. and Fortson, J. C. 1982. Stream temperature under an inadequate buffer strip in the southeast Piedmont. *Journal of the American Water Resources Association* 18:983–988. doi: 10.1111/j.1752-1688.1982.tb00105.x

Milly, P. C. D., J. Betancourt, M. Falkenmark, R.M. Hirsch, Z.W. Kundzewicz, D.P. Lettenmaier, and R.J. Stouffer. 2008. Stationarity Is Dead: Whither Water Management? *Science* 319:573-574.

[http://www.paztcn.wr.usgs.gov/julio\\_pdf/milly\\_et\\_al.pdf](http://www.paztcn.wr.usgs.gov/julio_pdf/milly_et_al.pdf)

Moore, R.D., D.L. Spittlehouse, and A. Story. 2005. Riparian microclimate and stream temperature response to forest harvesting: A review. *Journal of the American Water Resources Association* 41(4):813-834.

Pluhowski, E.J., and I.H. Kantrowitz. 1963. Influence of land-surface conditions on ground-water temperatures in south-western Suffolk County, Long island. USGS Professional Paper: 475-B, article 51, p. B186-B188. <http://pubs.er.usgs.gov/publication/pp475B>

Pollock, M. M., T. J. Beechie, M. Liermann, and R. E. Bigley. 2009. Stream temperature relationships to forest harvest in western Washington. DOI: 10.1111 / j.1752-1688.2008.00266.x. *Journal of the American Water Resources Association* (JAWRA) 45(1):141-156.

Rhodes, J. J., D.A. McCullough, and F. A. Espinosa. 1994. A coarse screening process for evaluation of the effects of land management activities on salmon spawning and rearing habitat in ESA consultations. Columbia River Inter-Tribal Fish Commission, Technical Report 94-4. Portland, OR. 245pp.

**Jeff Lockwood, Fisheries Biologist, NOAA/NMFS**

The systematic review focuses quite a bit on the two Groom et al. publications, and they do seem highly relevant. One caution though, as you may have heard from others (but perhaps the systematic review authors have not) there is a question whether at least some of the sites studied had trees cut down to the minimum required buffer widths. My understanding is that EPA reviewed the raw data and found that the median widths of the non-cut areas were larger than the minima. Without having reviewed the data myself, what I have heard from EPA is that the median widths for no cut buffers along the treated portions of designated treatment reaches were 80' and 64', respectively, for the right and left stream banks, on private lands and no cut zones were 154' and 131', respectively, for the right and left stream banks on state forest lands. If this is true, this suggests that the effects observed do not necessarily correlate with the minimum buffer sizes on private and state lands; in other words, the shade and temperature changes could have been larger if the minimum buffers were implemented.

<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
<p>The Forest Practices Act and State Forest Management Plan have both a no-cut width and a requirement to leave a certain amount of basal area of (conifer) trees within the riparian management areas (RMAs). The RMA width includes this no-cut width. Forest harvest operators tend to meet basal area requirements by leaving sufficient trees within the RMA immediately adjacent to the no-cut area. That is, the RMA beyond the 20' is generally not thinned but the clearcut may extend into the RMA to a distance where the basal area requirements are met. This practice facilitates the operational ease of harvest, and effectively creates no-cut buffers around streams that vary in width according to the riparian tree size, density, and composition. There is no evidence in this study that operators left more basal area than that required under the respective rules. Therefore, there is no evidence suggesting that the shade and temperature outcomes from RMAs in the study differ from those of RMAs harvested to the minimum of each respective rule.</p>	<p>Agree with ODF response.</p>

**E.2 External comments, and responses to these comments, on additions to the draft report (Executive Summary, and Geographic ranges and physical settings)**

**Mike Newton, Professor Emeritus – Silviculture, Dept. of Forest Engineering, Resources, and Management/Oregon State University**

When I look at these summaries, I suddenly realized that there were no data from streams that had no harvesting whatever along them. I am certain that there are occasional exceedances in virgin streams, especially those with alder riparian cover. This is a statistical matter. Intuitively, this would put somewhat wider boundaries on the spread of comparisons with the PCWS (*editor's note: PCWS refers to Oregon Dept. of Environmental Quality's Protecting Cold Water Standard*). In our work, there was substantial year to year variation before harvests that lead to uncertainty as to baseline warming trends.

<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
The SR protocol explicitly only includes studies that had treatments (i.e., forest harvest with some type of buffers around streams). In addition, the SR addresses how well studies controlled for background variation by using different types of controls. Groom et al. (2011b) specifically examined rates of PCW exceedances along unharvested streams (within the past 40+ years) and found a background exceedance rate of 5% when comparing two years of temperature data. However, many other studies did include pre-treatment temperature data with which to more accurately assess the treatment effect, even though the studies did not focus on the PCW.	Agree with ODF

I will maintain my concern that adherence to the PCWS is meaningless unless one considers the biological rationale for it. Water warmed returns to equilibrium in the reaches it flows into. Heat does not accumulate apart from equilibration with the environments into which it flows. None of this work was allowed to consider fish despite a rich literature showing that fish benefit from increased

primary production. thus my concern about all its findings for lack of biological relevance. To me, being a biological scientist requires asking questions that are germane to the biology rather than the politics of regulation. This study, conducted with precision and intensity, was great statistically, but failed biologically for having not asked the relevant question. So the scores are A+ and F.

<b>ODF Response</b>	<b>External Reviewer Response</b>
This comment is outside of the analysis' scope. The Board of Forestry made a decision on degradation based on the statutory obligation that ODF forest practices must meet DEQ water quality standards. We acknowledge the concern about biology. However, the analysis and the review are not and never have been focused on biology, rather on the addressing the Board's decision on degradation and subsequent need to have scientific backing for proposed rule alternatives.	Agree with ODF. We recognize that the SR question was purposefully limited, thus results must also be considered in light of the question that was addressed.

**Jeff Lockwood, Fisheries Biologist, NOAA/NMFS**

I am concerned that the executive summary (and perhaps the document it is summarizing - I did not check) is not accurately summarizing the "protecting cold water" criterion. The executive summary says this about the criterion in the first paragraph:

"This criterion prohibits human activities such as timber harvest from increasing stream temperatures by more than 0.3 °C at locations critical to salmon, steelhead or bull trout."

What is missing is the concept that each source does not get a 0.3 °C increase, it is the whole watershed. According to subsection (a) of OAR 340-041-0028 (11) [Protecting Cold Water], "This provision applies to all sources taken together at the point of maximum impact where salmon, steelhead or bull trout are present...."

If there are multiple streams in a watershed that are allowed to warm by 0.3 °C, the cumulative temperature increase downstream obviously could exceed this value. I recommend you correct this in the executive summary, and in the main document if necessary.

<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
Modification made in document.	Agree with modification

**Jeff Light, Hydrologist, Plum Creek Timber Company**

<b><u>Line #*</u></b>	<b><u>Comment/modification</u></b>	<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
GR	Change “west of the crest of the High Cascades” to “west of the Cascade Mt. Crest”	Fine.	Agree
GR	What are metrics for temperature in Figure 3b? 7-day max?	The studies used different temperature metrics, the details of which are found in Table 1 of the draft report (which is Table XX in the final report).	No comment
GR	What do you conclude from this with respect to the ability to extrapolate RipStream findings beyond the coast range?	This report does not make recommendations.	While the report does not extrapolate results, the synthesis shows that various buffer configurations in other Geographic Regions also do not always appear to meet the PCW standard. Added language to point out that the SR did capture apparent PCW exceedances for the FPA in the Interior Geographic Region.
ES	For the Executive Summary, I expect the way things are worded in a few places will lead to immediate questions from BOF members or others, and I’m curious what your responses will be to: 1. In the no-cut buffers discussion (line 94) you state: “Four of seven	An explicit part of the systematic review’s protocol was that the review would not include recommendations, including which buffer type or specific prescription is best at protecting cold water. Guidance will likely be based on additional data analysis.	No comment

<b><u>Line #*</u></b>	<b><u>Comment/modification</u></b>	<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
	<p>studies that measured stream temperatures had some sites that met the PCW standard, three of which had a range of buffer widths.” This means that the PCW was not met in 3 of seven studies, and some sites in the four that did meet the PCW did NOT meet the PCW. What guidance will you offer on these different outcomes?</p> <p>2. Your final conclusion (line 112) “The evidence from this suite of studies only supports two classes of rule alternatives as effective in meeting the Protecting Cold Water standard:</p> <ul style="list-style-type: none"> <li>• Variable retention buffers (including State Forest Management Plan)</li> <li>• No-cut buffers</li> </ul> <p>The variable retention buffers were so widely variable, and the State FMP buffers included cases with only one side of the stream harvested, so how will you respond when someone asks “which buffer is best”? Same question for no-cut buffers; they range from 10-ft to super wide. And there is a 20-ft no-cut in the FPA buffers which did</p>		

<u>Line #*</u>	<u>Comment/modification</u>	<u>ODF Response</u>	<u>External Reviewer Response</u>
	not <i>always</i> meet the PCW. Which is best?		
	A key conclusion that I read in the RipStream SER is that it is hard to guarantee a stream won't warm by 0.3C no matter how wide the buffer. This I think reflects that the change is too small to attribute to harvest – rather it could be driven by many other things. This point is important - I believe it should be in the Executive Summary. It will give the BOF a healthy dose of caution with the notion that they can 'cure' the problem with riparian management.	For a buffer prescription to meet the PCW criterion (i.e., not warm by more than 0.3°C), it does not need to meet this criterion in 100% of the cases. An example of this was found in Groom <i>et al.</i> (2011b) for State Forest Management Plan (FMP) buffers wherein the probability of meeting this criterion (91%) was not statistically different than streams without harvest, and thus these buffers are considered by ODEQ to meet the PCW.	We explain in the report that modifiers may affect results, but that the modifiers in each of the studies were too varied (and descriptions of how they were incorporated into the study design and analysis was not always available) to be incorporated into this analysis. However, the one commonality between the studies is that they test the effect of harvest.  We agree with ODF regarding their comments of how the PCW criterion is met.

\* GR refers to Geographic Regions Analysis; ES refers to Executive Summary.

**Maryanne Reiter, Hydrologist, Weyerhaeuser Co.**

For the Geographic scope document, the location described in line 2 is awkward. Maybe something simpler like Oregon west of the Cascade Crest, I don't know if is necessary to call it the high Cascade Crest, since crest implies the top of the range. A map of the study sites you used with your georegions would be good. I realize your georegions don't encompass WA or SE AK. You could use Ecoregions as a proxy to show they are similar in climate, etc.

<u>ODF Response</u>	<u>External Reviewer Response</u>
-Concerning high cascade crest, wording changed. -A map of all study sites would be unwieldy to make and overly	Agree with ODF. An additional problem to creating the map is that exact study locations would be challenging to identify.

busy to include in the report.	
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The georegion distinction will be important in interpreting what changes need to occur if one of the options chosen is more BA (*editors note: BA refers to basal area*) since the Coast medium streams require 120 sq ft BA per 1000 while W.Casc/Interior require 140. Would this difference in BA be enough to create difference in shade and temperature?

<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
Addressing a difference in basal area causing a difference in shade and temperature is beyond the scope of this review. Additional data analysis may address this.	Agree with ODF

Another question I have in the georegion document is about the interpretation of Brazier and Brown. I looked at their 1973 publication and could not find change in shade, but rather ACD (*editors note: ACD stands for angular canopy density*) for the harvested reach. Likewise with temperature, how was a change arrived at? Sorry if that is a late in the game question.

<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
-Angular canopy density (ACD) measures canopy cover, and cover should be included in axis title. Change in ACD is measured by subtracting the value measured at a buffer with that for 100 foot buffers. -Brazier and Brown (1973) report observed temperature change in Table 1. They measured this change as the difference in temperature between the upstream and downstream ends of the harvest unit.	Agree with ODF

In Fig. 3b of the georegion document it has in the legend a Q for the Morman study, but I did not see a Q in the figure.

<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
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-Mistake corrected.	No comment
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In the executive summary I feel the list at the end that indicates there are two only choices to meet the PCW need some caveats. The “Variable retention buffers (including State Forest Management Plan)” needs to indicate it is not just the buffer, but harvest strategy as well. The Ripstream data clearly shows that harvest strategy, that is, the number of sides of a stream harvested matters. Whether by plan or chance, it appears the State predominantly only harvests 1 side at a time as compared to private forest lands and this appears to influence whether the PCW is met or not. When 2 sides were harvested on state lands (n=2) the increases in temperature were 1.21 and 2.11 deg C, indicating there could be concern over 2-sided harvest on State lands. For private lands there were only 4 sites with 1-sided harvest; for those sites increases ranged from 0.03-0.53 deg C. It makes sense that leaving intact forest on one side of the stream can influence the thermal environment of the stream through shading and amelioration of microclimate.

<b>ODF Response</b>	<b>External Reviewer Response</b>
Harvesting one bank instead of two may influence shade levels at a stream and impact stream temperature changes. The two sites selected are not necessarily indicative of two sided buffers on State streams impacting temperatures. In the Groom et al. 2011 paper in Forest Ecology and Management, the third figure displays observed changes in temperature and predicted changes. The predicted changes were generated from a statistical model that examined all sites. The conditions at a particular site would cause that site to have a different temperature response than another site. Some variables in the statistical model did not change across years (e.g., stream gradient, length of the harvested reach). Other variables changed more frequently. Shade was measured once pre-harvest and once post-harvest. The change in the treatment reach temperature was summarized for each summer, as it was for the upstream control. If the stream banks were contributing greatly to the change in shade, and that change in shade was causing up to a 2 <sup>0</sup> C, we would have expected to see	<p>We agree with the reviewer that there may in fact be confounding variables that led to the results found in the RipStream study. The difference between one-sided and two-sided harvest may be a contributing variable to difference in stream temperature between the two management practices.</p> <p>Because we were unable to compare one-sided vs. two-sided harvest more universally for this systematic review, we do not want to draw conclusions based on number of sides harvested. However, it is worth noting that there are contributing factors that may influence stream temperatures and we have added language to the summary to that effect.</p>

a large drop in shade for these sites. Instead the two sites exhibited a 5% and a 2% drop in shade – not a lot compared to other sites.

For both sites we see agreement between the observed and predicted temperature change values. This is particularly true for the site that increased by  $> 2^{\circ}\text{C}$ . If there wasn't a large change in shade, how did the model predict the change in temperature? The only other variable that changes with frequency was the temperature change in the upstream control reach. Therefore, the increase in temperature in the treatment reach was likely not due to a change in shade, but rather in the temperature of the control reach.

The site that increased in temperature by  $1.21^{\circ}\text{C}$  had two distinct observations and predictions in the pre-harvest years. This indicates that the upstream control reach temperature behavior changed in that time period. The observed post-harvest treatment reach temperature changes were close (slightly greater than) the predicted values, indicating that the match wasn't perfect but that knowing the control reach temperature change assisted in approximating the post-harvest response.

**Mary Scurlock, Policy Analyst, M. Scurlock and Associates**

First, as I understand it the additional piece relating to buffer efficacy between geographic regions does not appear to address the question raised by Chris Frissell in the comments I submitted - i.e. whether available information supports the implicit but unsupported assumption that stream thermal dynamics are actually significantly different between regions. ("If the so-called "effects modifiers" are so different for these regions that stream thermal dynamics are fundamentally different, this should be demonstrable through specific data or analysis.")

<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
The Board made a decision in March 2013 approving the proposed systematic review only considering geographic regions west of the Cascade Crest (i.e., western Oregon). ODF staff support this decision since eastern Oregon has significantly different riparian vegetation and resulting shade responses to silvicultural prescriptions, and shade is the primary control on stream temperature examined in this review. Other effects modifiers are assumed to be similar between georegions in western Oregon.	The SR protocol was developed by ODF and vetted by stakeholders prior to our involvement with the project. We therefore have no additional comment.

The new section focuses instead on assessing whether available studies are adequate to demonstrate the relative efficacy of the same buffer prescriptions between regions, stating that: "data are only comparable between Geographic Regions when data assess the same buffer prescription from the same study conducted in more than one Geographic Region." This would seem to set up an unrealistically and un-necessarily narrow standard for probative studies. Although, technically, few -- if any -- of the identified studies used exactly the same specific buffer prescription, these prescriptions nonetheless produced end results that are comparable enough for them to be evaluated statistically. Therefore, the notion that identical buffer prescriptions have to be used to make any comparative study useful is false. Arguably, setting the proposed narrow standard is simply a way to stave off all relevant science and inference until some distant future when every possible option has been measured in a systematic study. But that has never happened, and it is unreasonable to expect it ever will happen. I submit that the definition of relevant science should not be narrowed to a single simplistic experimental paradigm. (Wasn't this a tactic long-used by the tobacco industry that is now being used to try to discredit science on climate change?)

<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
Our premise is that when trying to compare two quantities, it is essential that they be obtained in nearly the same way, especially when conducting a field science such as stream temperature monitoring wherein environmental variability is large. Methods of study design and data collection vary greatly between these	Add to ODF response that, for the scope of this SR, the statement in question is true. Comparison across studies would require analysis outside of our scope.

studies, thereby rendering a statistical comparison difficult and invalid.	
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Although the implication of this section is that there is not enough information to make inter-regional comparisons, on the other hand it would seem just as possible that the fact that "no clear picture emerges when comparing prescriptions' effectiveness" is not be due to lack of data, but to the fact that there simply isn't much of a difference in the underlying thermal processes at work.

<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
It's true that there may not be much difference in buffer efficacy between georegions examined in this review, as the pattern suggests (this is stated in the report). However, we cannot state that with a high degree of confidence due to the paucity of data (this is also stated in the report).	Agree with ODF

It seems to me that we should be interested in all studies that shed light on 1) the scientific basis for the different rule prescriptions we have, which vary between regions (i.e. are they based on empirically demonstrable differences in the physical processes at work?), and in; 2) the actual efficacy of the rules we are using in Eastern Oregon with respect to the prevention of management-induced stream warming.

<b><u>ODF Response</u></b>	<b><u>External Reviewer Response</u></b>
We agree that we should be interested in all studies that shed light on the scientific basis for different rule prescriptions, which is why we conducted this rigorous, evidence-based review of studies that directly relate to this suite of rule alternatives in western Oregon. We believe the extensive search and filter process, wherein 1,456 studies were assessed for relevancy to the review question, captured all the studies relevant to the review question. For the second point, eastern Oregon is not part of this review. We note the interest in assessing stream warming in eastern	Studies frequently do not provide enough information about the effects modifiers (which are sometimes surrogates for processes at work) to allow for a thorough review of all the contributing factors at play in a given site. Conclusions were drawn from the literature where possible, keeping in mind what data on effects was available for the majority of the publications. Most of this information could not be easily compiled, thus it can be found in reviews of individual studies in the Appendix.

Oregon for the upcoming revision of the Monitoring Strategy.	We received comments from other reviewers about effects modifiers. One example of our response can be found in Greg Haller's comments on lines 303-307; 354-356; and 592-600.
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